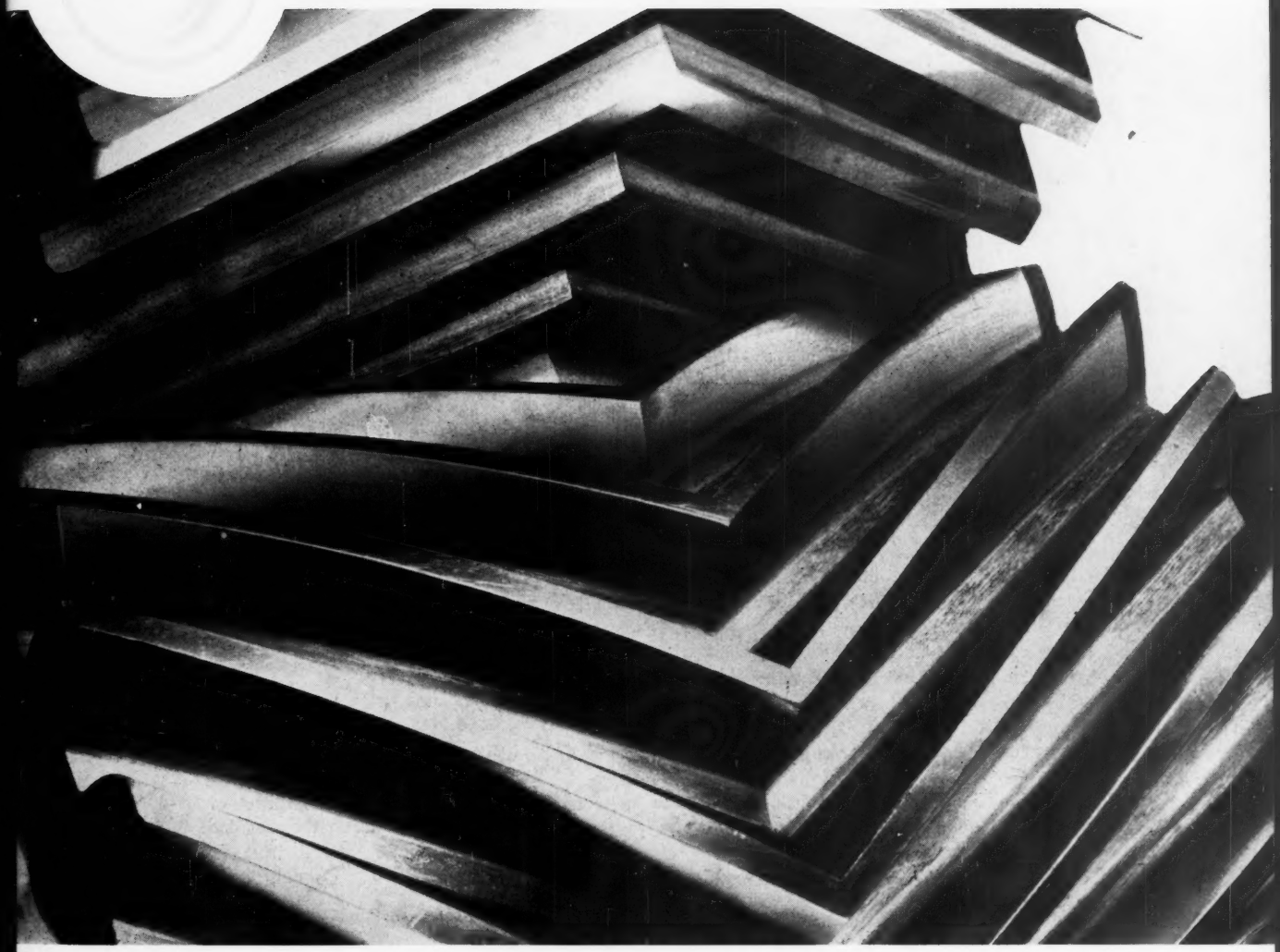
In this issue: REDUCTION OF GEAR FAILURES

APRIL, 1953

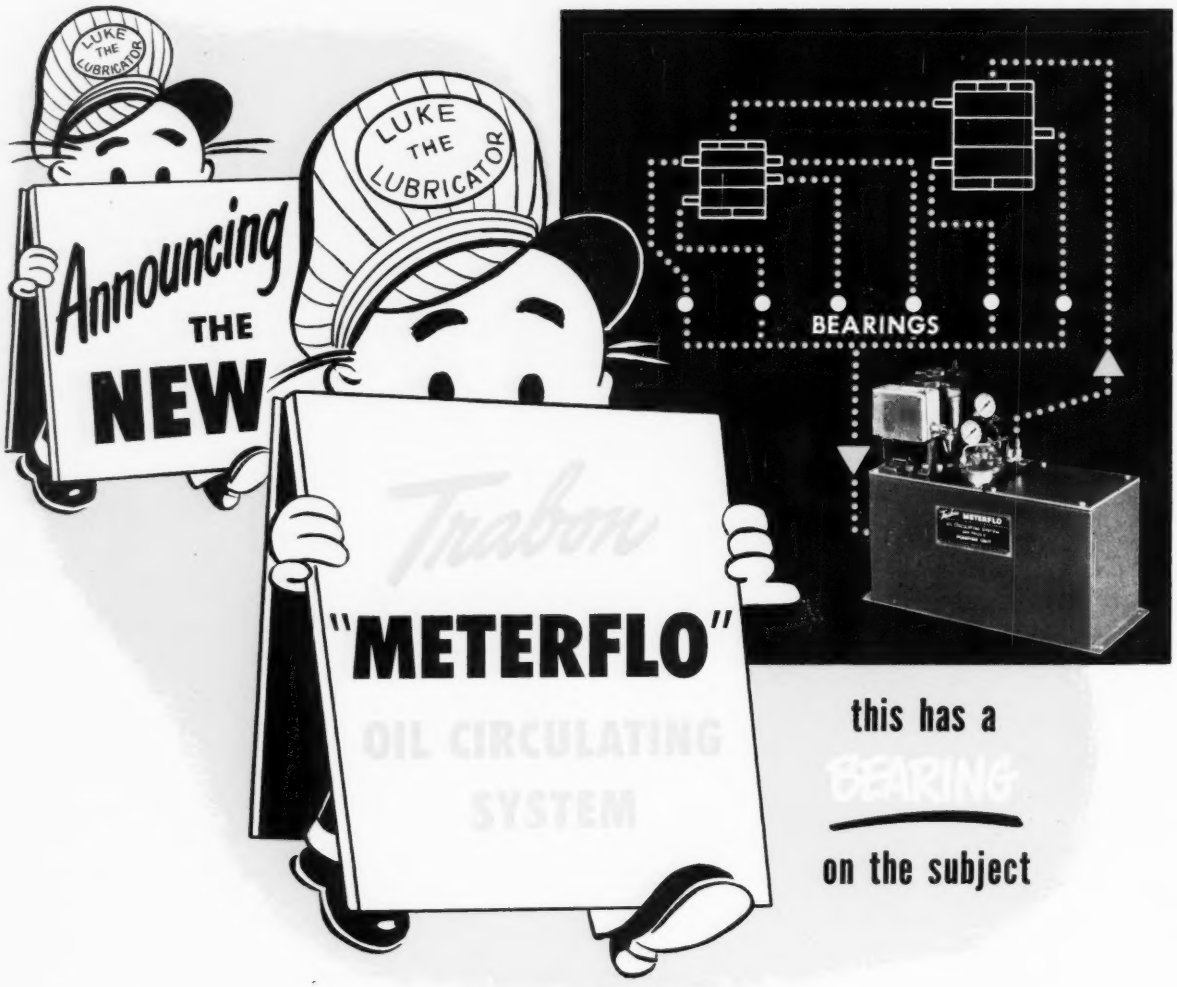
Vol. 9, No. 2

Lubrication ENGINEERING



HERRINGBONE GEARS

JOURNAL OF
THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS



Now... A Positive Method of Controlling the Flow of Oil to Every Bearing Under Pressure

- Utilizes the Trabon positive piston displacement principle.
- Flow rates up to 80 cubic inches per minute.
- RTP-2000 series Rotary Type Pump units available in complete range of discharge capacities.
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- Sturdy sump units include removable baffles for easy cleaning of tank.
- Type MXO and MO metering valves accurately control flow of oil to each bearing in the system.
- Pair of constantly blinking lights, actuated by flow of oil, available as optional signal equipment.
- The High-Low pressure switch, connected to the warning lights, permits ready identification of too-high or too-low pressure; blocked line; low oil supply; or will shut down the machine being lubricated.

Write for more information about this complete package unit today.

Trabon Automatic Lubrication Fits Any Bearing Situation

"We will see you at the ASLE Show in Boston, April 13-14-15, in Booth No. 14"

Trabon ENGINEERING CORPORATION

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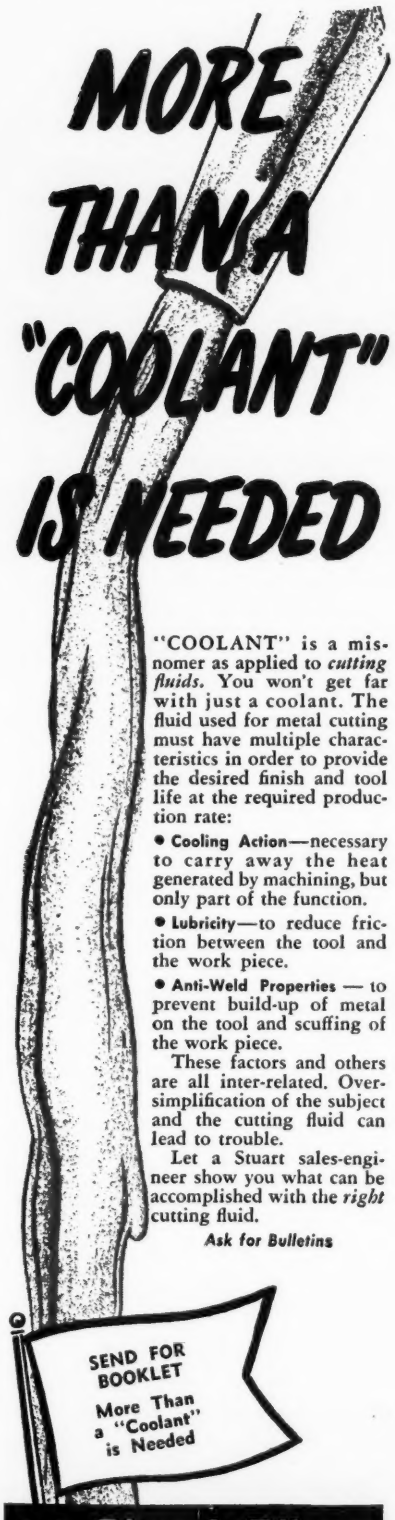
Oil and Grease Systems


MORE THAN A "COOLANT" IS NEEDED
"COOLANT" is a misnomer as applied to *cutting fluids*. You won't get far with just a coolant. The fluid used for metal cutting must have multiple characteristics in order to provide the desired finish and tool life at the required production rate:
• Cooling Action—necessary to carry away the heat generated by machining, but only part of the function.
• Lubricity—to reduce friction between the tool and the work piece.
• Anti-Weld Properties — to prevent build-up of metal on the tool and scuffing of the work piece.
These factors and others are all inter-related. Over-simplification of the subject and the cutting fluid can lead to trouble.
Let a Stuart sales-engineer show you what can be accomplished with the *right* cutting fluid.
Ask for Bulletins
SEND FOR BOOKLET
More Than a "Coolant" is Needed
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Time-Tested
Cutting Fluids and Lubricants

Lubrication ENGINEERING

APRIL, 1953, Vol. 9, No. 2

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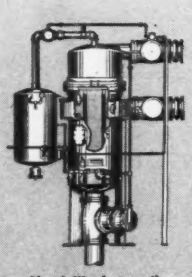
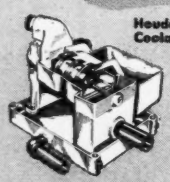
give your production dollars a 2-WAY STRETCH!

with HONAN-CRANE equipment

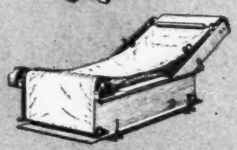
you can CUT COSTS and INCREASE PRODUCTION on all types of metal working operations



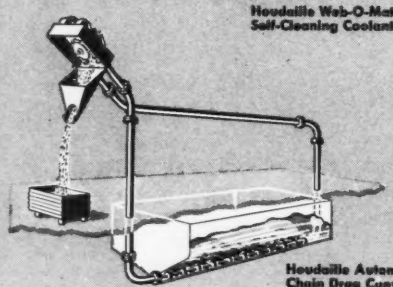
Houdaille Automatic Coolant Clarifier



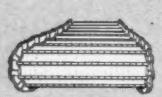
Houdaille Magnetic Coolant Filter



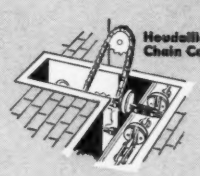
Houdaille Web-O-Matic Self-Cleaning Coolant Filter



Houdaille Automatic Chain Drag Conveyor



Houdaille Automatic Pan Type Conveyor



Houdaille Open Trough Chain Conveyor

Houdaille Slat Type Trough Conveyor

...the equipment:

Houdaille Automatic Filters

Keep oils and coolants clean, free from abrasive contamination, safe to use indefinitely. Complete line, including magnetic, web and clarifier types, for individual machine tools and central systems.

Houdaille Automatic Conveyors

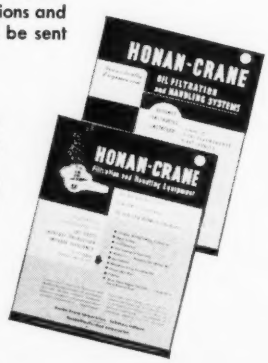
Provide low-cost removal and transport of chips, sludge, etc., to disposal point. Houdaille Conveyors are engineered for each type of metal-working waste handling problem.

...the results:

Honan-Crane Equipment steps up the efficiency of modern automatic plant operations . . . quickly pays for itself out of savings resulting from: • Fewer Product Rejects—Increased Production • Longer Tool and Wheel Life • *Much* Lower Maintenance Costs • Reduced Oil and Coolant Costs

write for full information

Illustrated Bulletins describing Honan-Crane equipment, typical installations and Metal Working Case Histories will be sent on request.



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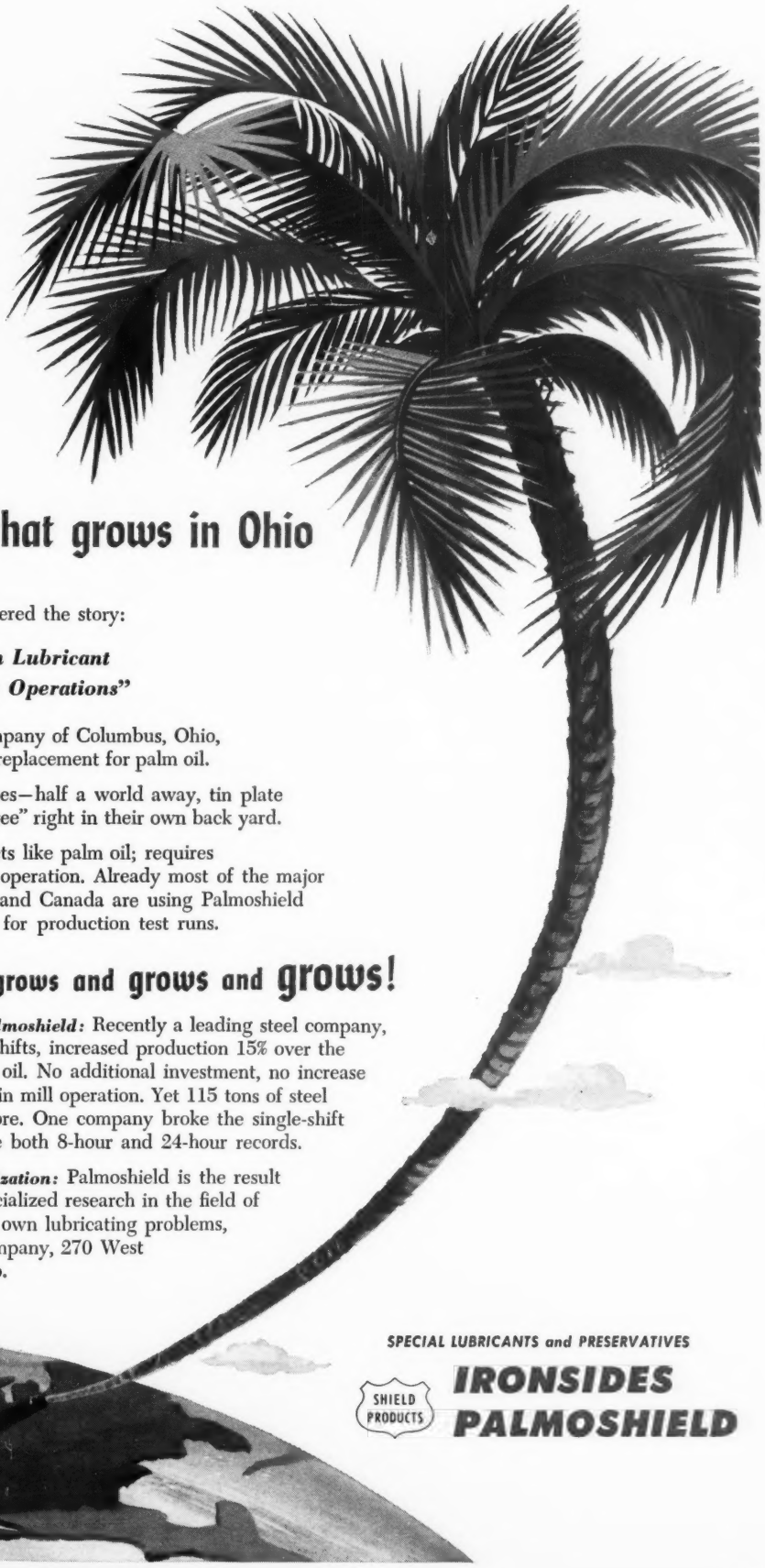


The palm tree that grows in Ohio

They planted it a year ago.
Leading steel publications covered the story:

"New All-American Lubricant For Cold Rolling Operations"

That's how The Ironsides Company of Columbus, Ohio, announced the first successful replacement for palm oil.

Instead of relying on palm trees—half a world away, tin plate producers now have a "palm tree" right in their own back yard.

Palmoshield looks, feels and acts like palm oil; requires absolutely no changes in mill operation. Already most of the major tin plate mills in this country and Canada are using Palmoshield for regular mill operations or for production test runs.

. . . and grows and grows and grows!

Production records set with Palmoshield: Recently a leading steel company, over a run of 20 consecutive shifts, increased production 15% over the average output with imported oil. No additional investment, no increase in manpower, and no changes in mill operation. Yet 115 tons of steel were rolled for every 110 before. One company broke the single-shift record, and still another broke both 8-hour and 24-hour records.

Backed by 60 years of specialization: Palmoshield is the result of Ironsides' sixty years of specialized research in the field of scientific lubrication. For your own lubricating problems, call or write The Ironsides Company, 270 West Mound Street, Columbus, Ohio.

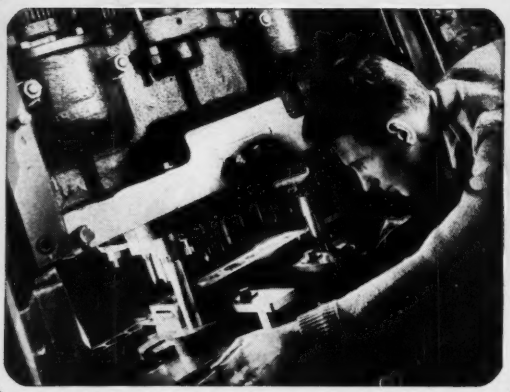
SPECIAL LUBRICANTS and PRESERVATIVES

SHIELD PRODUCTS

IRONSIDES PALMOSHIELD

telling the story of 'dag' dispersions

Here's a Dry-Film Lubricant that's Heat-Proof to 750°F.



'dag' colloidal graphite is the name. It comes dispersed in a variety of liquid carriers — water, oils, volatile hydrocarbons — which get it where it should go and then put it to work. Apply it by spraying, painting, or dipping.

Properties: Dry solid . . . softer than talc . . . unaffected by heat up to 750°F., and up to 3000°F. in inert atmospheres . . . conducts heat and electricity . . . dispersible in many fluids, co-dispersible with many solids . . . chemically inert, impervious to degreasing agents . . . anti-corrosive . . . low coefficient of expansion . . . gas-adsorbent . . . diamagnetic.

Uses: In forging, foundry and die casting, piercing, deep drawing, stretch-forming, extruding, spinning, wire drawing, ingot-mold stripping, press-fitting, cutting . . . for assembly and run-in . . . for permanent lubrication by impregnation or coating . . . in almost any process where friction-fighting is demanded at high temperatures.

Advice or help are yours for the asking. For literature on this unique material ask for Bulletins No. 424-12D and No. 435-12D.

Dispersions of molybdenum disulfide are available in various carriers. We are also equipped to do custom dispersing of solids in a wide variety of vehicles.

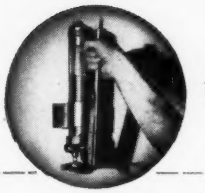
try resin-bonded dry graphite films for permanent lubrication

dag DISPERSIONS

Acheson Colloids Company, Port Huron, Mich.

... also ACHESON COLLOIDS LIMITED, LONDON, ENGLAND

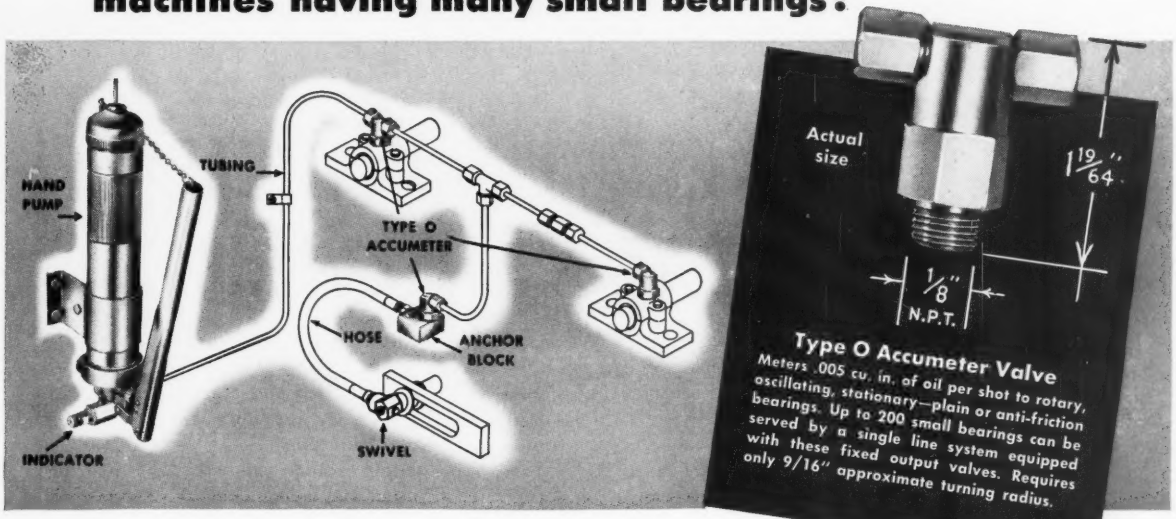
Units of Acheson Industries, Inc.



ideal...where close quarters make "ordinary" lubrication methods difficult...

ALEMITE® Accumeter® CENTRALIZED LUBRICATION

lets you design low-cost, automatic lubrication into machines having many small bearings!


HAND PUMP
TUBING
TYPE O ACCUMETER
HOSE
ANCHOR BLOCK
SWIVEL
INDICATOR
Actual size
1 19/64"
1/8" N.P.T.
Type O Accumeter Valve
Meters .005 cu. in. of oil per shot to rotary, oscillating, stationary—plain or anti-friction bearings. Up to 200 small bearings can be served by a single line system equipped with these fixed output valves. Requires only 9/16" approximate turning radius.

Tiny, simple, accurate . . . Alemite Accumeter Type O Valves make it easy to design low-cost centralized lubrication into small machines, precision machines, *any* machine having many small bearings concentrated in limited space!

From One Central Point...in a fraction of the time required for hand lubrication . . . Accumeter Type O Systems deliver an exact, measured amount of fluid oil to *all* bearings—*while the machine is in operation!* No points missed . . . production time saved actually increases machine output. No wonder 95% of the big plants buying machine tools specify *centralized lubrication!*

Type O Accumeter System serves single machines or groups of machines—will handle any fluid oil. It is just one of three types of Accumeter Systems made by Alemite to meet your exacting requirements.

offers...

ALL THESE ADVANTAGES!

- Eliminates shutdown time for lubrication. *Adds* productive time to machine output.
- Seals completely against dirt, grit, water all the way from "Barrel-to-Bearing."
- Prevents bearing troubles due to neglect or use of wrong lubricant.
- Services *all* bearings—including those inaccessible or dangerous—in one operation.
- Avoids work spoilage and bearing repairs due to over-lubrication.

FACTORY-TESTED . . . FIELD-PROVED

Proved in the field. Exhaustive tests showed *no variation* in the amount of lubricant discharged . . . even after 73,312 lubrication cycles, *equal to 122 years of twice-a-day service.*

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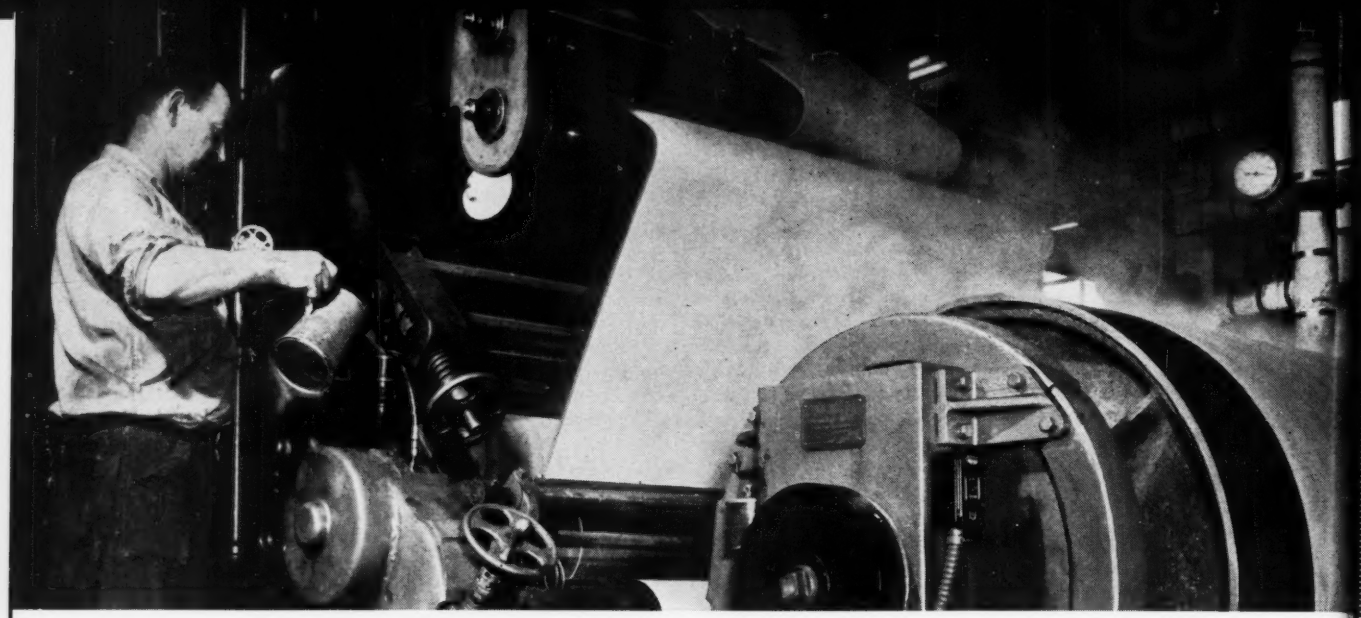


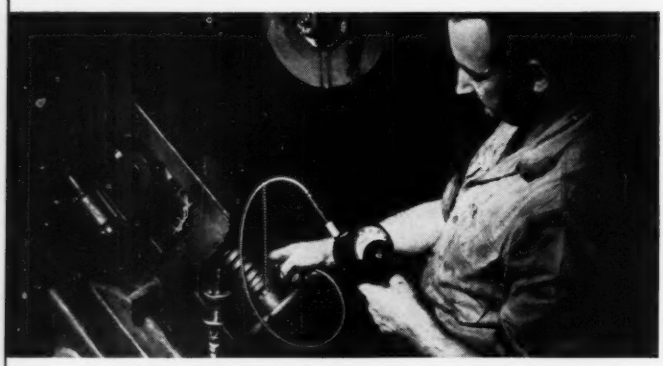
KRAFT IS PROCESSED AT 400 FT. PER MIN. in this corrugator. The two 78 in. corrugating rolls operate on roller bearings. Because the roll and bearing pressures are extremely high, the service is severe. A Sun oil keeps the bearings lubricated without hard-carbon formation.

NO CARBON FORMED IN 11 YEARS SINCE CHANGE TO A SUN LUBRICANT

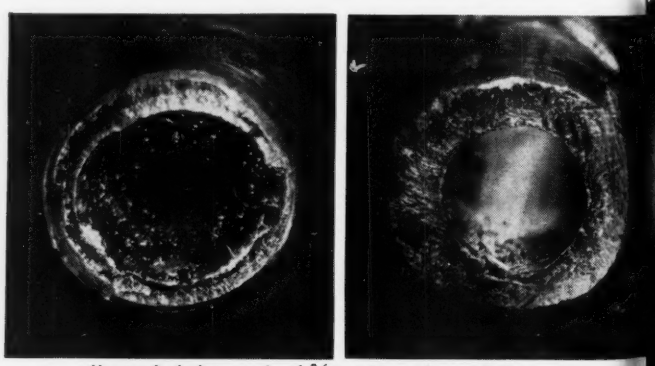
This kraft paper corrugator is lubricated by two systems —sight feed oiling and automatic force-feed. The oil in use 11 years ago to lubricate the roll journal bearings caused trouble. After only a few months' service, it formed hard carbon and clogged the lines and valves of the force-feed system. The roller bearings received insufficient lubrication and slowdowns were numerous.

The company then called in a Sun representative to study the problem. His recommendation—a Sun paper mill lubricant in wide use—was tried out and adopted. Oil lines, cups and regulating valves have remained clean and carbon free ever since. There has not been a single bearing failure due to faulty lubrication. A similar corrugator, installed about five years ago in a subsidiary plant, is also Sun lubricated. No bearing trouble has been encountered.

Sun's representatives and engineers have broad experience in all industrial fields. Their intimate knowledge of plant requirements is available to help you solve lubrication problems. For their advice or for information about Sun Industrial Products, just write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. LE-4.



BEARING HOUSING TEMPERATURES REACH 350 F because the corrugating rolls are steam heated. In spite of this condition, there's no indication of carbon deposits in or around the bearings or in the oil lines. Sun lubricants protect parts even when subjected to high temperatures.



Unretouched photographs of 3/16 in. tubing enlarged 8 dia.

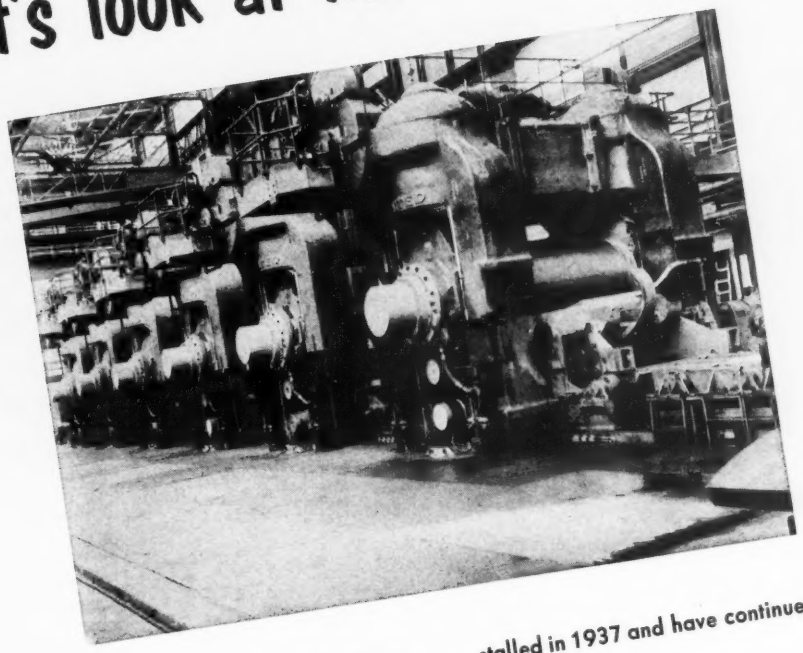
THERE'S NO COMPARISON between an ordinary oil and the naturally detergent grades of Sun oils. The photograph at the left shows the carbon and sludge formed by an ordinary oil. Photograph at right shows typical condition of line kept clean by Sun paper mill lubricant.

SUN INDUSTRIAL PRODUCTS

SUN OIL COMPANY, PHILADELPHIA 3, PA. • SUN OIL COMPANY, LTD., TORONTO AND MONTREAL

SUNOCO®

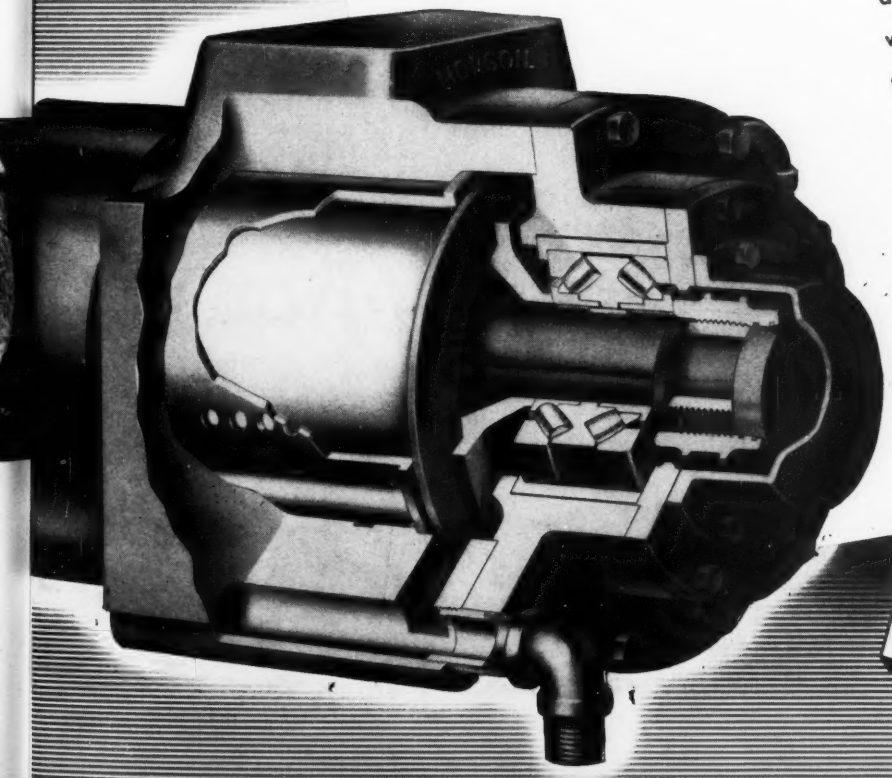
"let's look at the record . . ."



THIS picture shows Morgoil Bearings in operation in the four high hot strip mill at Corrigan-McKinney Works, Republic Steel Corp., Cleveland, Ohio. They were installed in 1937 and have continued to give outstanding service.

The reasons why Morgoils perform so efficiently stem from the simplicity of their design, their accuracy of manufacture and the basic conception that a bearing operating on a film of oil offers tremendous advantages from a load-carrying and wear standpoint.

Let us give you the full Morgoil story.



MORGAN CONSTRUCTION COMPANY

WORCESTER, MASSACHUSETTS

English Representative
International Construction Co.
56 Kingsway, London W. C. 2, England

MB-23

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...with TYCOL lubricants on hand!

Name any machine you can think of. There's a Tycol lubricant for it: For instance, what about heavily loaded gears and bearings? . . . Tycol Apreslube oils give you the tremendous load-carrying capacity you need. Electric motors? . . . Tycol Avalon oils or Tycol Armitage greases keep them running smoothly.

Steam cylinders? . . . Tycol Atwater oils resist the washing action of condensate. You always get top performance with Tycol lubricants. Why? . . . Because each Tycol grease and oil is manufactured from high quality base stocks and *tailored* for a specific application. Get the full story of the entire Tycol line from your local Tide Water Associated office today!

Over 300 Tycol industrial lubricants are at your disposal . . . engineered to fit the job!

REFINERS AND MARKETERS OF VEEDOL . . . THE WORLD'S MOST FAMOUS MOTOR OIL

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17 BATTERY PLACE - NEW YORK 4, N. Y.

MADISON-KIPP *Fresh Oil*

. . . FED UNDER PRESSURE BY THE MEASURED DROP

the most dependable method of lubrication ever developed!

This lubricator becomes an integral part of a machine tool in which there are 48 vital bearings that require dependable lubrication. The Madison-Kipp mechanism is so compact that the reservoir measurements are only 4" wide, 19¾" long by 5¾ high."

There are six different models to meet almost every application requirement. Please write us for all details regarding your particular lubricator requirements.

MADISON-KIPP CORPORATION
223 WAUBESA STREET • MADISON 10, WISCONSIN

kipp

• Skilled in Die Casting Mechanics • Experienced in Lubrication Engineering • Originators of Really High Speed Air Tools

DOW CORNING

Silicone Notes

ON LUBRICATION

REFERENCE NO. SL-54

FILE SILICONE LUBRICANTS

For more information please ask for Data sheet 3-201 on Dow Corning 200 Fluid; Data sheet 6-200 on Dow Corning 33 Grease.

DOW CORNING CORPORATION
Dept. BW-4, Midland, Mich.

DOW CORNING 200 FLUID

Materials with a combination of properties as unusual as those of the Dow Corning 200 Fluids invite experimentation. Quite often this leads to unusual applications. Some of them may be highly specialized, but all of them result in better performance or lower production costs. You will find a few typical applications reported in this column.

In planishing aluminum alloy sheet, tests in an aircraft plant indicate that a film of Dow Corning 200 Fluid minimizes scuff marks. Residual silicone is removed by solvent wash or degreasing.

On motion picture film, a 2% concentration of Dow Corning 200 Fluid in a solvent shows promise as a wipe-on lubricant. Film life is increased and the projected picture is not distorted in any way.

Crimper bars in a book binding plant don't scratch plastic bindings when lubricated with Dow Corning 200. The operator simply dips her finger into the silicone fluid and lightly touches two spots on every 200th cover. Enough silicone carries out on the bars to lubricate the next 199 covers.

In cutting magnesium, a manufacturer increases the life of his circular saw blades by brush coating them with Dow Corning 200 Fluid. He reports that one application per shift makes blades last 2 to 4 times as long in cutting magnesium; as much as 64 times as long as untreated blades in cutting steel-cored magnesium anodes.

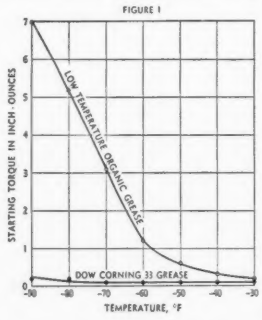
Phonograph records sprayed with a 10% solution of 200 Fluid are reported by an independent observer to become less dusty and to play with greater fidelity and less surface noise.

DOW CORNING 33 GREASE

Dow Corning 33 Grease, has better low temperature characteristics than organic greases that meet MIL-G-3278 specifications. It is also more stable than special high temperature petroleum greases at temperatures in the range of 300-400°F. Total loss due to bleed and evaporation at 300°F is comparable to that of good high temperature petroleum greases and less than half the loss measured for a typical low temperature synthetic grease that meets MIL-G-3278 specifications. At 390°F, total loss for Dow Corning 33 Grease is only 5.8% compared with 20 to 40% for the high temperature petroleum greases and 97% for the low temperature greases.

Low temperature performance is even more spectacular as indicated by a measurement of torque in bearings lubricated with Dow Corning 33 Grease and with a low temperature organic grease at temperatures in the range of —30 to —90°F. These data are plotted in Figure 1.

FIGURE 1



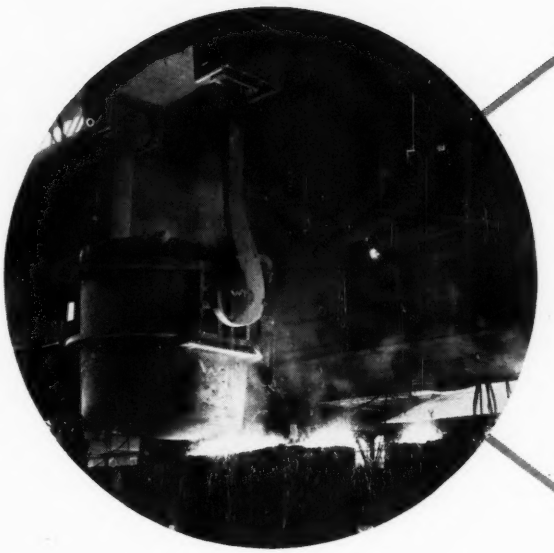
That's why Dow Corning 33 Grease is used as a lubricant for conveyor systems traveling through deep-freeze chambers; for bomb ejectors that must be operable at temperatures in the range of —70°F; and for camera shutters, rotating beacon lights, small synchronous motors and instruments exposed to both arctic and tropical temperatures and to outdoor weathering.

DOW CORNING CORPORATION • MIDLAND, MICHIGAN

ATLANTA • CHICAGO 1 • CLEVELAND 13 • DALLAS 1 • LOS ANGELES 15 • NEW YORK 20 • WASHINGTON 5, D. C. (SILVER SPRING, MD.)

CANADA: Fiberglas Canada Ltd., 50 St. Clair Avenue West, Toronto, Ontario ENGLAND: Midland Silicones Ltd., 49 Park Lane, London, W.1

DOW CORNING SILICONES



It's never too hot...

for PLASTILUBE, the revolutionary new lubricant that *just won't melt!* That's why it stays on the job longer at temperatures where soap base greases melt and run out.

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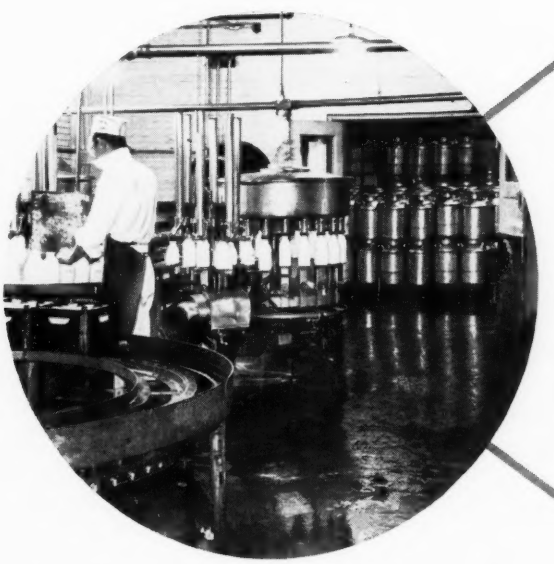

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Lubrication Engineering Short Courses

NORTHWESTERN

The Technological Institute of Northwestern University in Evanston, Illinois, is planning to offer a short course in Lubrication in the early summer from June 15 to June 24, designed to give a broad coverage of lubrication theory and practice. Theory and practice will be so interspersed throughout the course that both those having a limited knowledge and those having an extensive knowledge of lubrication can profit.

Among the many topics to be covered are: hydrodynamic lubrication theory, journal & thrust bearing design & practice, thin film lubrication, dry friction, solid lubricants, synthetic lubricants, chemical & physical tests, additives & detergents, specifications & specification practices, gear lubricants, and anti-friction bearings. Consideration will also be given to cutting fluids & coolants, deterioration & purification of lubricants, plant organization of lubricant systems, the place of lubricants, and lubricant systems in plant maintenance.

It is planned to limit the number of registrants to 50; the tuition fee, including costs of all classroom material, is $120.00. Arrangements have been made so that housing in one of the new University dormitories will be available for those in attendance. The course is under the direction of Profs. M. F. Spotts & B. H. Jennings at the Institute, and the complete program, registration forms and further information can be obtained by writing them.

M. I. T.

Engineers in industry will have an opportunity to study the applications of new techniques and methods in Lubrication Engineering during a two-week Special Summer Program from June 16 to 26 at the Massachusetts Institute of Technology.

The program is intended primarily for engineers responsible for lubrication maintenance and scheduling in industrial plants, and for chemists and others in the oil industry who wish to become better acquainted with the field of lubrication engineering. The entire program will be under the supervision of Prof. B. G. Rightmire, who is in charge of the Lubrication Laboratory in the M.I.T. Mechanical Engineering Department.

The course will cover a wide range of basic and specialized topics, including: theory of hydrodynamic lubrication and its application to the design of thrust & journal bearings; fundamentals of dry & boundary friction; bearing materials; fluid lubricants & greases of all kinds (including the various synthetic types); solid lubricants; gear lubrication; lubrication of rolling-contact bearings; lubricating systems; plant maintenance.

Further information concerning the special summer course in Lubrication Engineering and application blanks may be obtained from Prof. E. H. Huntress, Director of the Summer Session, Room 3-107, Massachusetts Institute of Technology, Cambridge 39.

Lube Lines

SCOPE OF PAPERS IN LUBRICATION ENGINEERING: As a result of the educational campaigns of ASLE and clarification of the scope of the now recognized profession of Lubrication Engineering, the editorial policies of this magazine have matured. The main text papers currently published fall into three general types: professional, technical and review. The first is designed to assist in setting up intelligent lubrication and maintenance programs. In the final anaylsis, acceptance of such programs depends on cold economic facts and actual case histories are valuable in directing efforts into profitable channels and in presenting achievements to management. Papers in this category are valuable if they provide the information needed by a man who has already had plant experience but is new in the position of Lubrication Engineer.

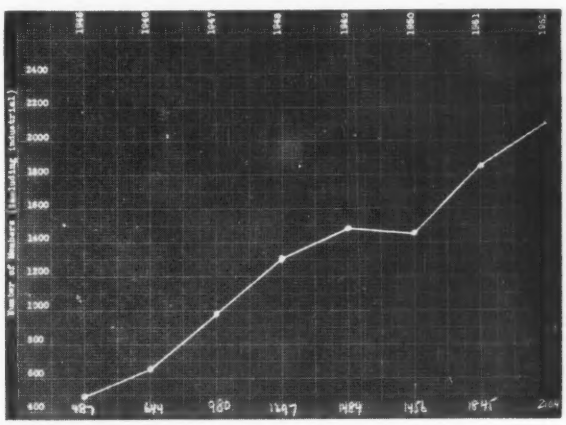
Technical papers cover the broad field of lubrication and include both experimental and theoretical endeavor in lubricant constitution, use and mode of application. A most important phase which has received too little attention in the literature of lubrication is the analysis of practical problems to discover what factors affect the choice of a lubricant supplemented by the development of significant test procedures to evaluate lubricants for these applications.

A definite function of ASLE is education. Lubrication Engineering is a newly recognized profession and has many facets. Educational articles are definitely in order. These must be interestingly written and must provide useful information to the neophyte without insulting the intelligence of the man of experience. Beyond giving a little background, generalities have limited value in these papers. Without question, this class of papers is the most difficult to write and offers a continuing challenge. S.K.T.

TECHNICAL JARGON: As spring rolls around, we again hear such familiar expressions as "the keystone sacker speared the horsehide hot off the old hickory and buzzed it to the hot corner for a double pay-off." To this we could add many other expressions in similar vein which would carry a world of meaning for the sports fan but which would require interpretation for the "layman."

The quotation is given to illustrate the universal development and acceptance of technical jargon to simplify and sharpen the exchange of information in every field of human interest. Surprisingly, however, while the acceptance of streamlined expressions is so widespread as to need almost no comment, there are those who object to the use of technical terms and ask authors to express themselves in "simple English." However, translation is by no means easy. Consider, for example, the plight of a mechanical engineer who must substitute for a technical expression "cam" the simplified designation "a rotating wheel with an irregular periphery which gives rise to reciprocating periodic motion in a mechanism." It would be better to use the word "cam" and to assume a knowledgeable audience. It is this very assumption which goes to the heart of the matter and the real question is really how much can be assumed. It is a happy author who strikes the right balance.

In the field of lubrication the problem is particularly acute because of the wide range of backgrounds of people interested in this subject. There are those, for example, with a vital interest in the subject who are just appreciating the differences between a mineral oil and a vegetable oil in regard to composition, performance and cost. There are also those who are applying the most complex mathematical analyses to such problems as the flow of lubricants in high speed bearings. All must exchange information and when they do, it is sometimes necessary to interrupt and ask for a translation. This applies to all levels. An operator may be asked in all reasonableness to define "four spokes of steam" by a chemist who himself is questioned about an "oleophilic surface-active agent." In summation, there is a field of common interest in lubrication and a cooperative spirit must prevail in giving and receiving technical information. S.K.T.



REPORT TO ASLE MEMBERS: The year 1952 showed the American Society of Lubrication Engineers continuing its record membership growth. The increasing demand by industry for greater lubrication controls and the emphasis on productive maintenance has greatly aided this increase. The accompanying chart indicates the Society membership totals for each year since its founding.

ASLE belongs to its members and its growth depends entirely upon them. Members can continue to help ASLE's growth by bringing their friends to Section and National Meetings. This introduction to the Society's activities creates new members which, in turn, helps the individual sections. The National Office stands ready to help in any way it can, whether it be in regard to membership, training courses, publications, or employment. Technical questions can be sent in and forwarded to the General Technical Committee for processing.

Many mechanical changes have been made in

(Continued on page 100)

REDUCTION OF GEAR FAILURES*

by S. D. Craine
W. A. Jones Foundry & Machine Co.
4401 Roosevelt Rd.
Chicago 24, Ill.

Mr. Craine graduated from the University of Illinois in 1928, College of Electrical Engineering, after which he was employed by the Illinois Bell Telephone Co. as a member of the Chief Engineer's Staff assigned to life analysis of physical plant. Following employment with the Socony-Vacuum Oil Co. as Lubrication Engineer assigned to steel mills and other heavy industry, he joined the W. A. Jones Foundry & Machine Co., manufacturers of enclosed gear trains, open gearing, and associated equipment, as Sales & Service Engineer.

ABSTRACT: The gear industry has developed the science of gear design and manufacture to the point that, with rare exception, the amount of work a pair of mating gears will do can be determined quite accurately. In general, gears are designed to last as long as the machine of which they are a part. There are, however, some applications in which the gears are considered expendable because of space limitations or where severe abrasives or destructive chemicals cannot be kept off the gears. Excluding these, the majority of replacement gears represent premature gear tooth failures—failures most of which could have been avoided. In only a few cases are the difficulties discovered before irreparable damage is done.

The Lubrication Engineer and the staff he directs are unique in that they frequently have opportunity to observe every gear train in the plant. This organization can be trained to interpret early indications of improper gear operation and thereby greatly reduce premature gear failures.

This paper is presented to give a breakdown of the major contributory causes of gear failures, the early indications to assist in their diagnosis, and recommendations for correcting the condition. The presentation is divided into five general headings; any one of the causes treated can spell success or failure in the physical life of gears.

MISALIGNMENT, VIBRATION & SHOCK: Gears of all types are cut to precise tooth surface relations and any deviations from these relations in operation will concentrate the loads in a small fraction of the required area of contact. In properly designed self-contained gear trains the housings are constructed and the bearings placed to allow the mating gears to adjust themselves to uniform distribution of load. Forces which prevent uniform tooth contact are external and are usually caused by: (1) distortion in the housing caused by improper mounting on the foundation or supporting structure, (2) excessive shaft deflection caused by exceeding the aligning limitations of the coupling, or (3) thrust resulting from mispositioning the input or output connecting shafts. In the case of open gear trains with bearings mounted on an independent structure a slight inaccuracy in placing the bearings or lack of sufficient bracing to prevent twisting in the structure will produce misalignment.

The initial indication of misalignment is a burnished line on the load side of the tooth at one end of the tooth and extending perpendicular to the pitch line. In extreme cases of misalignment a similar line on the back side of the tooth at the opposite end will also be noted. The high load concentration will soon produce enough localized heat to produce welding and scuffing of the area in contact. As loss of the surface metal develops the area in contact increases until ultimately it will cover most of the tooth surface. Furthermore, the heat developed in the early stages is high enough to appreciably reduce the hardness of the entire tooth surface. In the most severe cases the stresses developed at the root of the tooth are sufficient to ultimately cause fatigue failure.

Vibration is an insidious disease of machinery. Causes of vibration are many and sometimes difficult to trace. They can originate on the power side or on the delivery side of a gear train. Generally, the noise level of a properly designed gear train is relatively low. Very noisy gears practically always indicate the development of translatory or torsional periodic variations in power supplied to or accepted from a gear train.

With translatory vibration either perpendicular to or parallel to the axis of rotation our auditory and sensory nerve systems are the best indications of its presence. Its first destructive effect is to the bearings supporting the gear shafts. In a relatively short time either the bearing will fail or develop so much clearance that the gears will no longer carry the load on a full tooth contact. Inspection of the gear at this stage will show practically the same indications as discussed under "misalignment" although there was no misalignment at first. Even though the gear may not show too rapid a surface destruction a considerable amount of damage can be going on undetected at the root of the tooth in the form of fatigue producing stress.

In spur, helical, and straight worm gears a a vibration parallel to the axis of rotation will have little effect on the gears themselves. With herring-

*Paper presented at the 7th ASLE Annual Meeting, Cleveland, April 9, 1952.

bone, bevel, spiral bevel, hypoid, and double-enveloping worm gears the vibration parallel to the axis of rotation is very destructive.

Vibration in equipment containing gear trains can be present when equipment is new or may develop at any time. Once it develops it always gets worse—never corrects itself. The quicker its presence is detected and the basic cause eliminated the less the destruction to the bearings and gears will be.

Undue shock is a difficult factor to define and equally difficult to evaluate in most machines. The "heavy shock load" factor of 2 as developed by AGMA for application in the selection of gear reducers represents the effect of momentary overload for a short interval of time during a cycle. In general, this overload is in the range of 100 to 200 percent normal load. Undue shock represents a load condition in excess of 200 percent. Many machines such as shears, forging, and punch presses are designed to utilize the mass energy of flywheels to provide the momentary load requirement. Occasionally our imaginative production engineers will devise a new product or process for a machine which will overload the unit. Sometimes a flywheel will be introduced between a motor and a gear train to reduce speed variation. The net result may be an undue shock beyond the physical limits of one or more members of a gear train.

The initial indications on the gear of undue shock are easily observed. A highly burnished surface of the teeth in mesh at the point or points of maximum load indicates impending metallurgical failure of the tooth surface. Simultaneously a severe stress is developed at the root of the tooth which will cause the tooth to break off. The initial indication of undue shock must be taken seriously and either the work load reduced or other mechanical changes made to relieve the amount of shock absorption required of the gear train.

POWER DATA		GEAR DATA	
Type of Motor		Type Gear	
Operating Motor Speed	- Maximum	Tooth Form	
	Minimum	Diametral Pitch	
Operating Horsepower	- At Maximum Speed	Pinion	- Speed
	At Minimum Speed		Pitch Diameter
Circuit Breaker)	% above Full Load		Face
Overload Setting)	Time Lag		Material
FLYWHEEL DATA			Hardness
Motor Rotor	- Diameter	Ratio	
	Length (Core only)	Gear	- Speed
Supplemental Flywheel	- Diameter - Outside		Pitch Diameter
	Inside		Material
	Thickness		Hardness
	Weight		

Chart I—Essential data to determine operating gear loading.

IMPROPER LUBRICATION: The physical life of gears is very closely tied to lubrication propriety. Improper lubrication can shorten the life of a gear to a small fraction of its normal physical life. The gear industry is very cognizant of the fact that the incidence of premature gear failure is much less in plants supporting trained lubrication management. The term management is used advisedly to distinguish between a plant in which an individual is appointed to see that whatever lubricants are available are applied as often as he can make the rounds, and a plant in which a conscientious engineer is employed with full authority to establish a program to provide the best lubricant available for the application, direct the application thereof, and given sufficient cooperation by the engineering, operation, and maintenance staffs to correct operating faults which come to his attention.

In order to provide a realistic basis for the economics of lubricant selection for gears let us examine a typical case of depreciation cost of a conventional speed reducer and the annual cost of the lubricant employed. Based on a fairly large number of units of various power ratings and ratios the average speed reducer requires 10 gallons of oil for each $1,000 of first cost. Using an average life of 20 years the annual depreciation cost of this reducer is $50. If, however, an inferior lubricant is employed it is quite probable that this life will be shortened to 10 to 15 years. Using the conservative 15 years as an example the annual depreciation cost then becomes $67 or an increase of $17 per year. A complete oil change plus an estimated makeup of 50% makes the annual amount of oil required 15 gallons. A savings in the price of the oil of 50 cents per gallon would represent $7.50 per year. It will therefore be quite obvious that any compromise in the functional quality of the lubricant is false economy.

BASIC FAULT		INITIAL INDICATION
Misalignment	- Minor	Burnished line perpendicular to pitch line at one end of gear tooth on load side.
	Major	Burnished line perpendicular to pitch line at one end of gear on load side and on back of tooth at opposite end.
Vibration		High noise level in gears or in associated equipment connected therewith.
Shock		Burnished tooth surface on one or more points around the low speed gear.
Lubrication (Grade)		
Viscosity too low		Oil temperature above normal; gear surface temperature higher than oil temperature.
Viscosity too high		Oil temperature above normal; gear surface temperature same as oil temperature.
Lubrication (Type)		
Need for Heavy)		Highly polished surface in dedendum of driving
Duty Oil)		gear; occasional scratches perpendicular to pitch line.
Metallurgy		Highly burnished surface of contact area with feathering at tip.
Treatment		Hairline checking in contact area.
Design - Gears		Noisy; off pitch line contact; rapid wear.
Bearings		Excessive clearance; heat in housing around bearings.
Housing		Mounting lug breakage; oil leakage; loosening of assembly bolts.

Chart II—Initial indications of gear failures.

In the selection of the ideal viscosity for any gear train there are many factors that must be considered. There is no simple practical formula that would be useful to the plant lubrication engineer to calculate the viscosity value for each of the applications in the plant. The manufacturer of the enclosed gear train has carefully determined this value and either stamped it on the nameplate or incorporated it in the instruction manual. If the writer can draw on his own experience the term "high quality mineral oil" would mean a double inhibited turbine grade oil of not less than 80 VI for splash systems and not less than 60 VI for circulating systems.

Quite frequently a gear train is called upon to operate under conditions other than those for which it was purchased. Sometimes a motor of greater horsepower, or of the same horsepower but of lower speed, or a V belt drive to reduce the input speed is used. If this is the case the Lubrication Engineer should check the rating of the reducer for the proposed input speed and class of service. He should also secure from the power engineer the actual maximum and average power being delivered to the unit. If the maximum power is of short duration and relatively infrequent and is between 100 to 150 percent above the Class 1 rating of the gear train or if the average power is

from 5 to 50 percent above the correct Class rating for the input speed then the lubricant should be changed from the straight mineral oil specified to a leadnapthenate type heavy duty gear oil. In units in which either the bearings or gears are bronze, the oil should be negative for the ASTM Copper Corrosion @ 210 F. If the power input exceeds 150% for the maximum or 50% for the average, get a new reducer or train of gears of proper rating and save the present set for some future application.

An inspection of the gears will very quickly indicate a condition of improper lubrication. The first step in the inspection should be made immediately after the unit is shut down. The temperature of the oil in the housing and the temperature of the tooth surfaces should be taken simultaneously. The latter may be taken with a contact pyrometer. The three causes of elevated temperatures in enclosed gear trains due to the impropriety of the lubricant are: (1) too high a viscosity, (2) too low a viscosity, and (3) the need for an extreme-pressure type lubricant. The use of too heavy a lubricant in gear trains having high pitch line velocities will produce excessive heat due to the fluid friction. In this case the lubricant and the tooth surface will have about the same temperature. When the lubricant is too light the temperature will be the result of metalic friction. When this exists the temperature of the lubricant will be high and the temperature of the tooth surfaces considerably higher. This same temperature relation will develop when the pressure-velocity relation exceeds the limitation of a straight mineral oil.

Before a decision is made concerning the above causes, an inspection of the tooth surfaces should be made. A properly lubricated gear will show a smooth dull surface throughout the area of sliding contact. A highly polished surface and a few scratches in the direction of slide indicate the need for an extreme-pressure type lubricant. Close inspection of the scratch will usually show a small pit or tear at the beginning of the scratch. This is the first stage of welding. Small pits along the pitch line does not indicate a lubrication failure or a metallurgical failure or excessive load. It is a condition that is part of the initial mating of the gears and stops as soon as the microscopic high points in the surface have worn off.

Although lubrication and metallurgical failures frequently take place at the same time some of the cases are primarily due to lubrication. The high temperature which may develop from lubricant inadequacy can reduce the surface hardness of steel or bronze gears to the point where they not only wear faster but are more susceptible to welding. Spalling frequently is abetted by this loss of surface hardness. On the other side of the ledger it is occasionally found that the lubricant has been completely successful and still the gear shows rapid deterioration. This condition will be treated in a later section of this paper.

IMPROPER METALLURGY & HEAT TREATMENT: The advent of premature gear failure resulting from improper type of metal employed or heat treatment given to gears is less frequent than the other causes treated herein. Its incidence may be the result of inadequate controls or tests in the manufacturing process but more frequently is the result of an error in selection or change in the load demand.

The factors involved in the selection of the material for gears and the treatment used are so many and varied that they are beyond the scope of this paper. However, the early indications of impending trouble should be understood so as to apply corrective measures or to prevent future duplication. Metallurgical failure can be either fatigue or the development of stresses beyond the yield point of the surface metal the end result of which is severe spalling of the teeth, peeling off of a layer of metal or severe loss of contour resulting from metal flow.

A new gear being placed in service under heavy load will usually develop a blotchy burnished surface. As soon as proper mating and work hardening of the surface is completed the surface will lose its mirror appearance. However, if the burnished appearance expands to cover full contact and continues to exist and also the tooth shows evidence of feathering at the tip the yield point of the metal is being exceeded. The next stage in the evolution of metallurgical failure is the development of microscopically fine cracks in the dedendum of the driving gear or pinion. At this stage quick action is important; first drop the load appreciably; and second get an order in for a new gear of at least 25 percent more load carrying capacity. Since the driven gear is usually cast steel and the frequency of contact on each tooth is less than on the driving pinion the burnished appearance will be slower or not at all. On the driven gear the microscopically fine cracks can develop unnoticed, the first indication of difficulty being a few flat chunks falling out, usually from the addendum. Serious loss of contact surface on the driving gear by spalling will in a short time cause a like condition on the driven gear because of the increase in unit area loads.

IMPROPER GEAR, BEARING & HOUSING DESIGN: There is hardly need to mention that any machine is as strong as its weakest component. When one element fails, damage usually occurs to some if not all of the other elements. There are very few applications for gears in a modern machine that will tolerate sloppy gears and also very few machines where the failure of the gears does not take the machine out of production. The cost of the gear train usually represents a sizeable portion of the total cost of the machine. It is there-

(Continued on page 98)

LUBRICATION OF MODERN REFRIGERATION EQUIPMENT, by K. Borah, Shell Oil Co., will be featured in the June issue of LUBRICATION ENGINEERING as the seventh in the series of Practical Lubrication articles. At the conclusion of this series, the Society will publish the papers in book form as another of its practical lubrication manuals.

RELATION BETWEEN BEARING CLEARANCES & BEARING LIFE WITH SILICONE GREASE AT 150 C.*

by G. Grant
Dow Corning Corp.
Midland, Mich.

Mr. Grant received his B. S. degree in Electrical Engineering from the Massachusetts Institute of Technology in 1936. Upon graduation he was employed by the Delco Appliance Div. of GMC and later by the U. S. Graphite Co. In 1943 Mr. Grant joined the technical staff of Dow Corning Corp. where he was placed in charge of the Motor Test Program conducted by Dow Corning in collaboration with Westinghouse Electric Corp. under the sponsorship of the U. S. Navy Dept. This program was initiated in 1943 to evaluate the performance of silicone electrical insulating resins and silicone greases. Mr. Grant has co-authored several technical papers and articles on the practical applications of silicones as electrical insulating materials and lubricants and is a member of the AIEE and ASLE.

ABSTRACT: It has been noted that in the high temperature life testing of various greases a wide dispersion in the life of ball bearings lubricated with silicone oil-lithium soap grease was obtained, while bearings lubricated with organic oil-metallic soap greases showed a relatively short but more uniform life under test conditions that were supposed to be identical. This indicated that there were test factors irrelevant in the life of the more conventional greases at 150 C. but potent enough to reduce the life of bearings lubricated with the silicone grease to a time comparable to that of the organic oil-metallic soap greases or to permit a life expectancy in the range of 15 to 20 times the shorter runs. Further study of the test conditions and data showed that the life of ball bearings lubricated with silicone oil-lithium soap type grease is a function of the mechanical fit-up of the bearing assembly as well as the thermal stability of the grease. This leads to certain recommendations designed to reduce or eliminate premature failure in silicone lubricated bearings.

INTRODUCTION: The development of a wide variety of greases designed to meet the military and industrial demand for lubricants that will give longer life at extreme temperatures or over a wide temperature span has made evaluation difficult. In an effort to evaluate some of these new greases, an extensive Navy-Industry Cooperative High Temperature Grease Testing Program was conducted over a period of years. This paper is a by-product of that program designed to evaluate various greases as lubricants for the ball bearings of electric motors operating at high temperatures[1].

TEST PROCEDURE: All tests reported in this paper were conducted on two electric motors of the same design. These totally enclosed non-ventilated squirrel-cage induction motors were equipped with a 310 ball bearing at the front end. This bearing was locked on the shaft with a standard ABEC lock-nut and washer. The other bearing is not considered here.

The motors were belt loaded to bring the temperature of the outer ring of the test bearings up to 150 plus-or-minus 5 C. This resulted in a speed of about 1700 rpm. Under these conditions the inner ring of the bearings operated at a temperature about 13 C. above that of the outer ring. All of the test bearings were specially heat treated for high temperature service and every precaution was taken to assure proper alignment and to maintain cleanliness.

New bearings lubricated with a fixed quantity of grease were installed for each test run. No grease was added nor was the assembly handled in any way during the test runs. The motors were operated for 150 hours and then shut down for 18 hours. This cycle was repeated until the bearing failed. Failure was taken to be that point at which the operating temperature of the bearing became excessively high for a continuous period of time, or the bearing became continuously noisy and caused excessive vibration, or the bearing froze and caused the rotor to lock. Five different organic oil-metallic soap type greases and two silicone oil-lithium soap type greases were subjected to this test cycle.

TEST RESULTS: This test procedure disclosed a wide variation in the life of bearings lubricated with silicone oil-lithium soap type greases. Some variation was expected but end points ranging from 336 to 7,443 hours seemed entirely unreasonable. Furthermore, the grease in the bearings that failed prematurely appeared to be in good condition except where it came into immediate contact with the balls and raceways. In the long runs the grease showed definite deterioration throughout the reservoir.

Study of the test results showed that one of the two motors produced most of the early bearing failures. It was found that the diameter of the shaft of this motor was several ten-thousandths of an inch larger than the shaft of the other motor. The larger shaft was then cut down so that both shafts had the same diameter. After that was done, bearings on test in both motors followed a reasonable distribution pattern of long runs.

The obvious conclusion was that the shaft fit had been too tight even though it met ABEC specifications. Expansion of the inner ring, due to a tight press fit plus the reduction of radial clearance caused by the temperature differential between the inner and outer raceways, eliminated all radial clearance and placed the balls under compression. This produced loads too heavy for the grease to carry successfully. Such failures were caused by mechanical conditions however, and not by deterioration of the grease due to high operating temperatures.

*Paper presented at the 7th ASLE Annual Meeting, Cleveland, April 8, 1952.

Since radial clearance appeared to be such an important factor in determining the life of silicone oil-lithium soap type greases in this test program, the shaft fit, the end play, and the life in hours are recorded in Table I. The data on bearing life were plotted as frequency distribution bar graphs for each type of grease in Fig. 1.

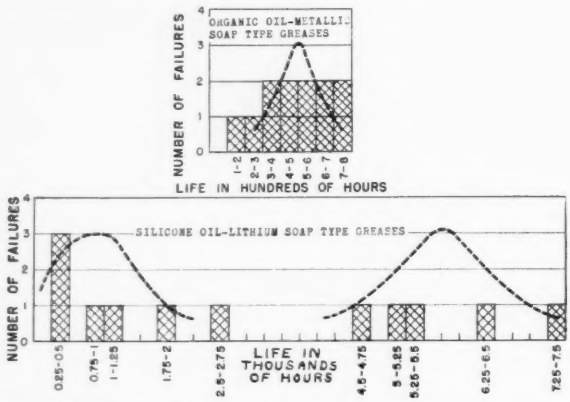


Fig. 1 Frequency distribution of bearing failures.

These data clearly show the relatively consistent results obtained with organic oil-metallic soap type greases in spite of the fact that several different types of grease were tested and in spite of such variables as shaft fit-up and end play. This indicates that thermal decomposition in the greases made with organic oils was much more rapid than breakdown due to extreme loads.

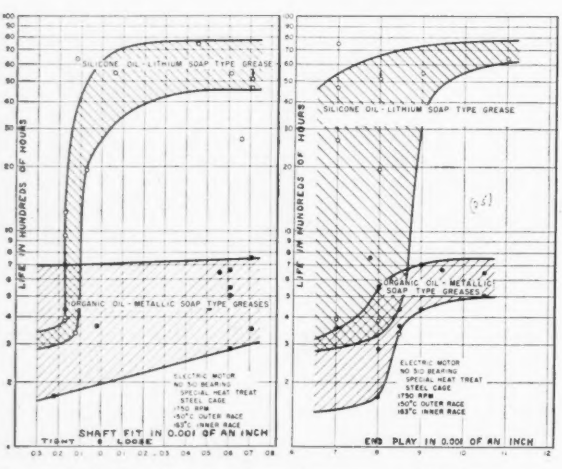

SILICONE OIL-LITHIUM SOAP TYPE GREASE
ORGANIC OIL-METALLIC SOAP TYPE GREASES
LIFE IN HUNDREDS OF HOURS
SHAFT FIT IN 0.001 OF AN INCH
TIGHT
LOOSE
END PLAY IN 0.001 OF AN INCH

Fig. 2 (left) Ball bearing life as function of shaft fit.

Fig. 3 (right) Ball bearing life as function of end play.

The silicone oil-lithium soap type greases, on the contrary, are heat-stable enough to give very long service at high temperatures if they are not subjected to extreme load conditions. In order to obtain a truly authentic probability picture, many more runs should be made. It is, however, likely that if a large number of runs were made with both tight and loose fits, distribution curves very similar to those shown in Fig. 1 would be obtained.

BEARING LIFE AS A FUNCTION OF SHAFT FIT: Perhaps the most interesting data are shown in Fig. 2. Here the failure points are plotted as a function of shaft fit. The life of bearings lubricated with organic oil-metallic soap type greases is affected very little by shaft fit. In the case of the silicone oil-lithium soap type greases, the fit on the shaft is very critical. More data would be desirable, but the trend is so marked here that this curve can be taken to be a reasonable representation of life expectancy. For this assembly, operating under these conditions, the critical value for shaft fit is from one to two ten-thousandths tight. In that range a very great variation in results will be obtained. With tighter fits, poor life is to be expected. Very satisfactory life will generally result from a looser fit.

It is interesting to note that the maximum life point at 0.00012 inches tight was recorded for the bearing with the largest internal clearance as indicated by an end play of 11 mils. This suggests that a press fit can be used if there is enough radial clearance. If more tests were run with bearings having a large radial clearance, the whole curve would probably move to the left, permitting tighter shaft fits.

BEARING LIFE AS A FUNCTION OF END PLAY: As supporting evidence, bearing life was plotted as a function of end play in Fig. 3. Again more points would more accurately define the area of life expectancy. However, a trend exists and the areas shown give a relatively good picture of what may be expected of an assembly of this size operating under these test conditions. End play is only a rough measure of radial clearance in the bearing, but a large end play frequently indicates loose internal fit, permitting more expansion of the inner race before putting the balls under compression.

SILICONE OIL-LITHIUM SOAP			ORGANIC OIL-METALLIC SOAP		
Shaft Fit Mils	End Play Mils	Hours Life	Shaft Fit Mils	End Play Mils	Hours Life
0.17-T	8.0	387	0.22-T	8.0	172
0.17-T	7.0	390	0.17-T	8.5	437
0.17-T	-	954	0.17-T	9.0	706
0.17-T	-	1208	0.02-T	8.5	361
0.12-T	8.5	336	0.51-L	9.0	433
0.12-T	11.0	6368	0.56-L	10.5	647
0.07-T	8.0	1940	0.61-L	9.5	661
0.45-L	7.0	7443	0.61-L	8.0	284
0.61-L	9.0	5433	0.61-L	10.5	505
0.66-L	7.0	2694	0.61-L	8.0	552
0.71-L	7.0	4639	0.71-L	7.0	352
0.71-L	8.0	5148+	0.71-L	7.8	754

Key: T - Tight, L - Loose

Table I LIFE DATA. Ball bearing tests at 150 C. No. 310 bearing, steel cage, special heat treatment. Front bearing of belt loaded totally enclosed non-ventilated electric motor. Motor loaded until outer race operated at 150 C. and inner race at approximately 163 C.

Fig. 3 shows that among the bearings tested an end play of about 0.009 of an inch is the critical value. With that much or more end play, silicone oil-lithium soap type greases give long service life. At less than nine thousandths of an inch, bearing life was very erratic. The wide variation for the tighter bearings is probably due to differences in the shaft fit. It is likely that if the line representing maximum life for bearings lubricated with silicone oil-lithium soap greases could be extended to lower end play values, it would approach the minimum life line. This would indicate consis-

(Continued on page 97)

THE INFLUENCE OF SOLID SURFACE FILMS ON THE FRICTION & SURFACE DAMAGE OF STEEL AT HIGH SLIDING VELOCITIES*

by E. E. Bisson
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Mr. Bisson attended the Universities of Vermont and Florida, receiving his B. S. degree in Mechanical Engineering from the latter in 1938. He joined NACA at Langley Field in 1939 and served successively as Research Engineer and Project Engineer; in 1943 he was transferred to NACA's Lewis Flight Prop. Lab. as Head of the Piston Ring & Cylinder Barrel Research Section, in 1945 being named Head of the Lubrication, Friction & Wear Research Section. At present he is the NACA representative on the Co-operative Research Council's group on Aircraft Gas-Turbine Engine Bearings & Their Lubricants, and a member of the NACA Sub-committee on Lubrication & Wear.

INTRODUCTION: The NACA has been interested for some time in the basic influence of solid surface films on friction and surface damage, particularly at high speeds. Results of NACA research in this field are discussed in detail in Refs. 1 through 7. Because of the severe requirements imposed on lubricants for turbojet and turbopropeller engines and the consequent possibility that marginal lubrication may occur, supplemental lubrication is sometimes required[8]. This supplemental lubrication is defined as the protection which must be provided against surface failure and high friction when the normal lubricant film becomes ineffective. With respect to means of accomplishing this protection, solid surface films can be quite effective provided they can be maintained in place at the surface. The easiest means of maintaining a film at the surface is to utilize a self-repairing film but other types of films can be effective for limited periods of time. Both the self-repairing and other types of films will be discussed later in the paper.

THEORY: Before discussing experimental results on various solid films, the generally accepted theory of dry friction and the development of friction theory to predict the effect of solid surface films should be reviewed. As is undoubtedly well known, present friction theory is based on adhesion between surfaces. Two theories of friction, independently advanced at about the same time by Dr. Merchant in this country[9] and Dr. Bowden in England[10], propose that the friction force is equal to the sum of two terms: a shear term and a ploughing or roughness term. Appendix A shows the development of these two theories. In many instances (for example, when the surfaces are quite clean), the shear term is the more important of the two and the second term can be neglected.

The contact of the surfaces is through surface asperities and it has been postulated that plastic flow occurs at the actual area of contact (the surface asperities) until the real contact area is great enough to support the load. It should be noted however that the surface contact stress is not a nominal value but is equal to the flow pressure (the yield strength in compression) of the material at the surface. As Appendix A shows, the coefficient of friction is equal to the ratio of shear strength to this yield strength. The reduction in friction coefficient is, therefore, dependent on the reduction of the value of the ratio of shear strength to yield strength either by decreasing shear strength, increasing yield strength, or both. Obtaining both conditions in one material is practically impossible because those materials with low shear strength have low yield strength and vice versa. However, by the use of low shear strength films (with thicknesses as low as millionths of an inch) on hard base materials, both desirable conditions may be obtained. We can obtain low shear strength at the surface without appreciably decreasing the yield strength of the combination. Any load will be supported through the film by the hard base material while friction is maintained at a low value by the presence, between the surfaces, of the film. These low shear strength films can be of the following types: fluid lubricants, oxides, sulfides, metals, etc.

On the chemical side it is a well known fact that the presence of certain films has increased load carrying capacity of some surfaces. In fact, NACA studies have shown that, when steel surfaces are properly run-in, there is formed, on the surface, natural films of iron oxides, primarily Fe_3O_4 (Ref. 6). Surfaces showing good run-in properties have also produced natural films of FeO (Ref. 1). On the other hand, for surfaces which had not run-in but had shown incipient failure, there was formed on the surface a natural film of Fe_2O_3 (Ref. 6). These facts illustrate the importance not only of oxides per se but of specific types of oxides on friction. These facts may also show why there has been considerable controversy about whether the oxides or iron are good or bad from a friction standpoint. There are many references in the literature which give opposite views to this question and this was one of the reasons why NACA was interested in obtaining fundamental information on specific oxides of iron.

Another important but frequently neglected function of surface films is to act as a contaminant for the prevention of welding or adhesion between the surfaces which are in such intimate contact. The better the bond between film and

*Paper presented at a meeting of the ASLE Pittsburgh Section, May 18, 1951.

surface, the better the resistance to rupture of this film and, in consequence, the better the protection from welding.

In agreement with this view, Ref. 5 shows that the presence of naturally formed surface films was of appreciable benefit from the standpoint of prevention of surface failure by welding.

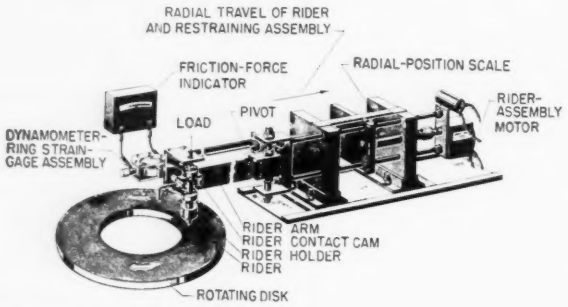

Fig. 1 Sliding friction apparatus.

APPARATUS: The NACA research was carried out with specimens of steel on steel and, where solid surface films were used, they were applied to one of the pair of specimens (the disk). The solid surface films which were investigated included, besides the oxides of iron, a variety of materials which were either the type which could be utilized as supplemental or dry lubricants or the type believed to be formed as a reaction product (between the additive and iron) when extreme pressure additives are used in lubricants.

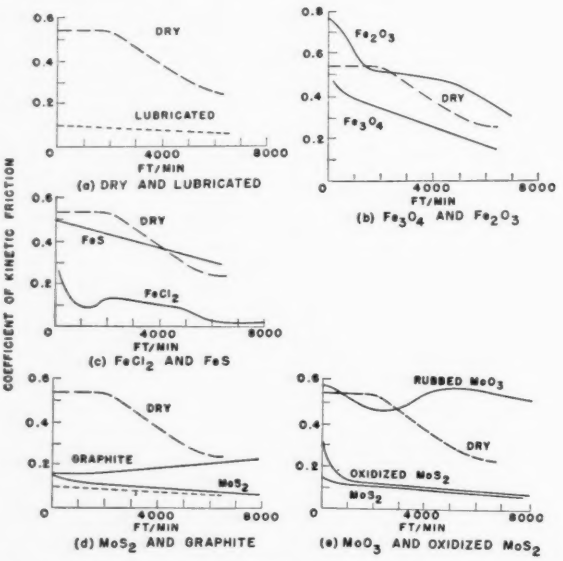

Fig. 2 Friction at high sliding velocities of steel-on-steel under various surface conditions.

The apparatus used in the NACA investigation is shown in Fig. 1. The friction apparatus utilized in these experiments is essentially that of Ref. 1 with some modifications. It consists of a rotating disk on which slides a spherical rider. The rider is elastically restrained so as to permit the measurement of friction force. In most runs, the rider transverses a spiral path across the disk so that the rider is usually sliding on virgin surface of the disk.

RESULTS AND DISCUSSION: The friction data obtained with various surface treatments of the disk are presented in Fig. 2 and the surface appearance of the wear spot on the rider specimen after these individual experiments are shown in Fig. 3.

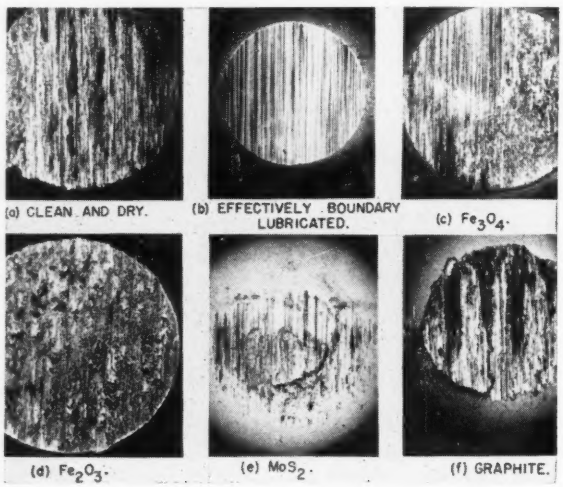

Fig. 3 Surface appearance of rider specimens after sliding against disks with various surface treatments.

The results for steel on steel are shown in Fig. 2 (a). The data indicate that friction coefficient of dry steel follows Amontons Law (by being independent of sliding velocity) to 1600 feet per minute only; beyond this value of sliding velocity, there is a marked downward trend. A downward trend is also indicated for the lubricated specimens. The surface appearance of the ball specimens after dry and lubricated runs is shown in Figs. 3 (a) and 3 (b). The photomicrographs show that surface failure by welding has been taking place for the dry specimens while no surface failure is evident for the lubricated specimens. The welding for dry steel has been particularly violent, resulting in appreciable "tearing-out" and metal transfer.

It is the belief at NACA that the explanation for the downward trend of the friction coefficient with increase in velocity is the result of formation of beneficial oxide films because of increase in rate of heat generation at the sliding surfaces. (It should be noted that even under lubricated conditions, there is plenty of oxygen available for reaction with the surfaces.) In partial confirmation of this view, when the steel slider was permitted to transverse the same wear track on the disk, FeO was identified as the chief constituent of the wear debris. At the same time, there was an appreciable reduction in friction coefficient. It is reasonable to assume that the FeO film was being formed at all times; allowing the rider to transverse the same track on the disk merely permitted the FeO film to attain a thickness such that the film became visible to the naked eye. The gradual decrease in friction coefficient could be the result of the gradual increase in film thickness to a limiting thickness which was so great that further increases in thickness were balanced by rupture of the film;

thus a condition of equilibrium between film build-up and film break-down could be obtained and the friction coefficient could then also reach an equilibrium condition.

Because of the importance of oxides, data were obtained on films (1200 Angstrom units thick) of the specific oxides, Fe_3O_4 and Fe_2O_3 (Fig. 2(b)). These data, as well as visual examination of the surfaces, show that Fe_3O_4 can be quite beneficial in decreasing friction and, what is more important, in preventing welding (Fig. 3(c)). In comparison, Fe_2O_3 showed high friction (Fig. 2(b)) and excessive welding (Fig. 3(d)). With any given surface film of small thickness (such as the 1200Å Fe_3O_4 film, for example), an increase in sliding velocity could be expected to decrease friction coefficient by increasing surface temperature; this increase in temperature would decrease shear strength (in equations of Appendix A) without appreciably decreasing bulk hardness (Ref. 10).

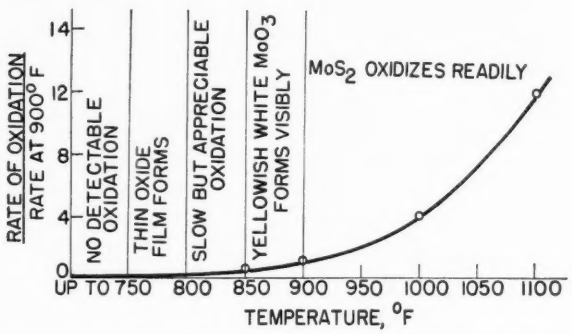

Fig. 4 Oxidation characteristics of MoS_2. (Data from Ref. 3).

Fig. 2(c) shows results with solid surface films of a type which might be formed by reaction of extreme pressure additives with ferrous surfaces. These data along with visual examination of the surfaces show that both FeS and $FeCl_2$ are effective in preventing welding although $FeCl_2$ is much more effective than FeS in reducing friction. If the reaction products from additives of the sulphur and chlorine types are primarily FeS and $FeCl_2$ respectively, the effectiveness of the chlorine type should be appreciably superior.

Solid surface films other than the oxides are believed to be of enough importance to warrant appreciable study. In accordance, Appendix B shows a review of the physical and chemical properties of some materials which were believed to have promise as solid lubricants. The properties of most importance are melting point, form of crystalline structure and tenacity for steel. On the basis of these properties, the materials which were chosen for further study were MoS_2 and graphite. A preliminary electron diffraction investigation was made of these two materials formed as films on the surface of steel. On the basis of this diffraction study, the graphite film was shown to be highly oriented with the lamellae parallel to the steel surface and the MoS_2 film was shown to be randomly oriented. Since both of these materials have a lamellar structure, shear within the material (in the plane of the lamellae) should occur readily.

The exp. friction results with MoS_2 and graphite are shown in Fig. 2(d). The results show that there is little choice between the two materials at low speeds (and room temperature) but the curves diverge with increase in sliding velocity. The graphite film was apparently failing and allowing welding to take place as shown in Fig. 3(f). In comparison, MoS_2 showed no welding (Fig. 3(e)) and no film failure, resulting in low friction at high sliding velocities (Fig. 2(d)).

Since MoS_2 looked promising in the investigations at room temperature, it was also considered as a possible high temperature lubricant. Before its use at high temperatures however, it was necessary to check its chemical stability at elevated temperatures. An X-ray diffraction investigation at high temperatures and in the absence of oxygen showed that there were no phase changes of the MoS_2. In the presence of oxygen however, X-ray diffraction and other investigations showed that MoS_2 will oxide to MoO_3 at a very low rate at 750 F.; the rate of oxidation increases steadily and becomes high at temperatures of 1050 F. or greater. These results are shown in Fig. 4.

In accordance, the friction characteristics of both an oxidized film of MoS_2 and a rubbed film of pure MoO_3 were studied. The results are shown in Fig. 2 (e). The results show that MoO_3 is a very poor lubricant with high friction and excessive welding occurring. The oxidized MoS_2 film, however, showed results remarkably similar to those for the unoxidized MoS_2 film.

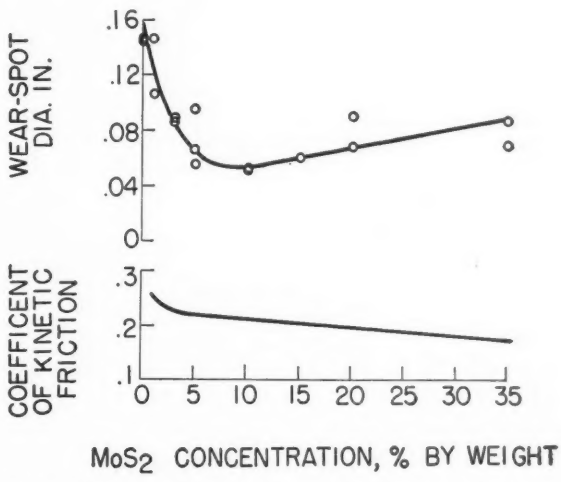

Fig. 5 Wear and friction of hot pressed bearing material containing MoS_2. (Data from Ref. 4).

In order to get some physical concept of the mechanism of action of the MoS_2 in the oxidized and unoxidized conditions, consideration must be given to the actual surface films in both conditions. While these experiments were designed to give as near complete oxidation as is practical, undoubtedly that fraction of the MoS_2 which is unoxidized (even though this fraction be less than 0.1 percent) acts as an effective solid film lubricant at the surface because the unoxidized fraction undoubtedly is adjacent to the steel surface (furthest from the available oxygen). These results indicate (as predicted by theory) that the film immediately adjacent to the surface is that which produces the beneficial results.

Because of the success of MoS_2 under these

(Continued on page 100)

EFFECTS OF MODERN DESIGN TRENDS ON BALL BEARING RESEARCH*

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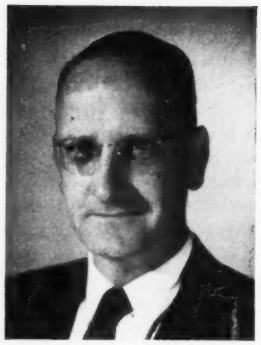

Mr. Cobb graduated from Pratt Institute in 1928 (Electrical Engineering) and has since been in the employ of the New Departure Div., General Motors Corp., with the exception of 1942 & 1943 when he was employed as Ass't Chief Engineer with the Draper Corp. At New Departure, he has served in a number of capacities including Product Design Engineer, Physical Test Engineer, Executive Engineer, Ass't to General Manager, and presently Manager of Research & Development.

The trend in machine tools, aircraft, power or auxiliary units, heat exchange units or for that matter, in any component mechanism, is toward reduced size for compactness or weight reduction, greater power output per unit weight and higher speeds. The moving bodies of such components must be supported on bearings which are generally of ball bearing types and the bearing requirements are for smaller bearing sizes operating at ultra high speed, maximum limit loading under ambient temperature conditions of up to 350 F., under the usual conditions, and as high as 1200 F. in a few instances. Also, in some cases, the bearings must operate in closed systems containing gasoline, sodium, sodium potassium, water, etc., and the usual lubricants cannot be applied.

The bearing industry and designers have limited background on most of these design conditions, as heretofore most laboratory testing and usage of bearings in actual operation had a top temperature range of 200 F. and only a top temperature of 300 F. in unusual instances. All existing ball bearing load ratings are based on 90 to 135 F., and the temperature function was never considered important enough to include in capacity formulae. Also, throughout the industry in general, all bearing load capacities are based on 52100 steel for rings and 51100 steel for balls. Separator studies were very sparse with guess estimate taking the place of actual thorough investigations. Oil lubrication has always been recommended for high speed, heavy load, and high temperature applications.

The present trend toward high speed, high temperature, and heavy loading does not allow us to continue with our past practices and we must now look to other than oil-lubricated bearings for compactness and weight elimination and steels which will not draw at temperatures up to and over 1000 F. if we are to keep abreast of designers. In fact, the very future of our country from a military standpoint depends on the ability of industry to find quickly bearing designs and materials to meet these drastic design requirements.

This article will attempt to show what has been investigated and the trend of the results of these investigations. It should be borne in mind that these investigations are far from complete and, therefore, in most cases show merely a trend instead of absolute factual conclusions from the limited data so far accumulated.

THE EFFECT OF ROCKWELL HARDNESS OF 52100 STEEL ON BEARING ENDURANCE: As basic 52100 steels have proved so successful in ball bearings operating under normal loads, speeds, and temperatures, it is only logical that this material should be thoroughly explored to determine the highest temperature it can withstand and still be usable to some degree for ball bearing parts.

The first study was made on bearing components drawn to various Rockwell hardnesses and then endurance tested under usual heavy over-load test conditions at normal speed and temperatures. In this case, Rockwell hardness readings were obtained at room temperature (80 F.) prior to and after testing and showed no change in hardness regardless of test duration as was expected, as test temperature was maintained at 130 F. as measured on bearing outer rings. Test loading was 2480 lbs. radial at 2000 inner ring rpm, SAE 30 oil jet lubrication, 3208 bearing size, load factor f = 0.54 (i.e., load factor = manufacturer's catalog-rated load divided by the actual operating load or so-called pay load and expected life of 323 hours.)

Fig. 1 shows Rockwell hardness Rc at 80 F. versus correction factor which, when applied to handbook load ratings, will indicate the load rating of a bearing made of 52100 steel rings and 51100 steel balls when steel has been drawn to a given Rockwell hardness measured at 80 F. Note that bearing capacity is markedly affected by variations in hardness.

It is, of course, known that Rockwell hardness varies with time and temperature and room temperature Rc is not a true index to use, but rather hot hardness should be used. Sufficient tests have been made to indicate that for operating temperatures of up to, roughly, 150 F., 52100 and 51100 steels are fairly stable as presently heat treated, but at higher temperatures steel becomes progressively more unstable with time and temperature.

Tests were, therefore, run to establish the relation of room temperature Rc to hot Rc and their relative change with time and temperature. These tests are far from complete but trends have been obtained within a temperature range of 100 F. to 350 F. for 1000-hour intervals as shown in Fig. 2.

It will be noted that the room temperature or cold hardness Rc of samples held at a given tem-

*Paper presented at a meeting of the ASLE New York Section, October 18, 1951.

perature shows a continual drop-off in Rc with time, whereas the hot hardness Rc shows a rapid initial drop-off and then shows an indication of slight increase in measure of Rc hardness for a given period and then further indicates Rc hardness decrease. This work is being extended to a temperature range of 100 to 100 F. for 1000 hours. In addition to obtaining the relation of hot hardness to time and temperature, actual bearings, all having an initial hardness of Rc 63 at 80 F., are being run at operating temperatures of 40, 100, 150, 250, 350, 450 and 550 F. as measured on bearing outer ring, to determine bearing life relationship to material hardness as governed by time and temperature. All test bearings are 3208 size under 2480 lbs. radial load, 2000 rpm, and viscosity of oil for all test temperatures being maintained constant and equivalent to the viscosity of SAE 30 oil at 200 F. When this test is completed on the effect of time and temperature on 52100 steel ball bearing life, the information will be correlated with published capacity formulae in the nature of a hardness, time, and temperature correction factor similar to that previously shown in Fig. 1.

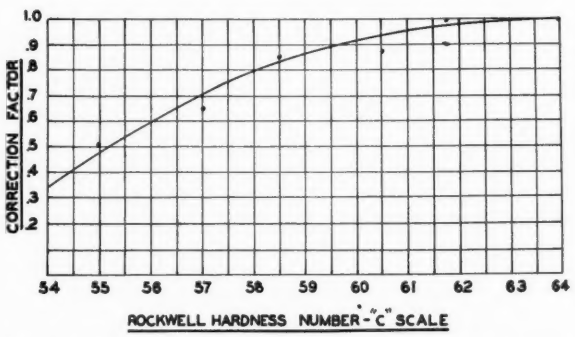

Fig. 1 Rockwell hardness bearing capacity correction factor.

DIMENSIONAL STABILIZATION OF BEARINGS MADE OF 52100 STEEL: In applications where bearings must operate at fairly high temperatures, care must be used in selecting interference fits between bearing and bearing housing and shaft, especially if the housing and shaft are of different materials having different thermal expansion rates from 52100 steel. Material volume change with time and temperature must also be considered as these factors may seriously affect bearing internal fit-up and cause heavy bearing preloading with consequent early bearing fatigue failure. The volume change of 52100 material after hardening, as shown in Fig. 3, is such as first to decrease in volume (phase a of the volume-time curve or a' depending upon the drawing temperature), then an increase (phase b or b') and then again a decrease in volume (phase c or c'), to approximately initial volume, and these volume changes, when they occur in an assembled bearing due to time and temperature, will have a direct effect on radial clearance. Decreasing volumes tend to increase radial play and increasing volumes tend to decrease radial play.

In making bearing rings and balls of AISI 52100 and 51100 modified steel respectively, an attempt is made to so heat treat that the material is totally converted to martensite. This degree of perfection is, of course, nearly impossible to obtain and some amount of austenite will be retained. In an operating bearing, time and temperature will affect material volume as shown in Fig. 3.

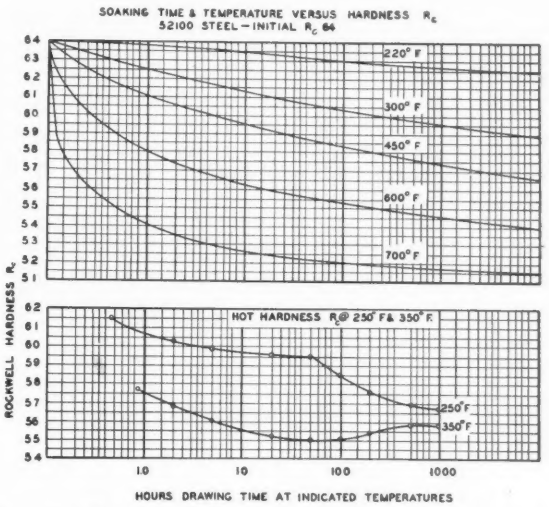

Fig. 2 Relation of Room Temperature Rc to Hot Rc.

During the tempering operation two structural changes are taking place simultaneously, namely: the conversion of retained austenite to martensite and the conversion of martensite to ferrite and carbides. These are directly opposite in affect as the conversion of martensite to ferrite and carbides decreases volumes, whereas the conversion of retained austenite to martensite increases volumes initially until such time as the effect of the newly formed martensite, in turn being converted as previously explained, results in a decrease in volume. While these structural changes are taking place simultaneously the rate of effect is not the same, resulting in a volume change as indicated in Fig. 3. The speed with which these two structural changes take place and the degree to which volume changes occur are directly connected with time and temperature, as shown by the dotted line in Fig. 3 with tempering over "X" temperature and by the solid line for tempering under "X" temperature where "X" temperature is approximately 350 F.

The cycle of volume change of 52100 steel affecting internal bearing fitup can be taken care of within limits by stablizing bearing parts 40 to 50 F. above operating temperature with a minimum stablizing temperature of 350 F. for a given time. Such stabilization removes the hook on the curve to the extent that drastic volume changes are eliminated and minor changes which may occur can be compensated for by internal bearing geometry.

After the volume change cycle is completed there is no repetition, unless the material is rehardened. In stabilizing rings and balls the above volume change cycle is reasonably completed so that it will not occur in operating bearings in customers' applications. However, the drawing operation to diminish volume change also reduces Rockwell hardness which, it has been noted, also reduces bearing life. Therefore, since it is not desirable to draw rings down any lower than necessary in order to obtain as much bearing life as pos-

sible, phase "c" is not entirely completed except for high temperature operation. As standard drawing temperature is 350 F. for one hour for 52100 bearing steel, it is not necessary to stabilize bearings for operation up to 300 F., but at higher temperatures a stabilization at 40 to 50 F. above operating temperatures is probably advisable. Higher drawing temperatures, as indicated by the dotted line in Fig. 3, hasten volume cycle change and assure more complete conversion but Rockwell hardness is sacrificed. It is suggested that the lowest Rockwell hardness at 80 F. be 59 Rc. This means that the maximum bearing operating condition for which stabilizing 52100 steel would normally be considered is 350 F. If higher temperatures are encountered, hardness versus life should be considered before using 52100 steel rings to insure adequate life is available.

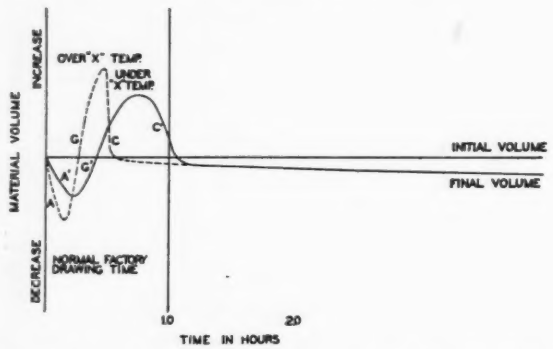

Fig. 3 Effect of time and temperature on relative volume of steel.

HIGH TEMPERATURE STEELS FOR BALL BEARING COMPONENTS: The aforementioned data pertain only to 52100 steel. Experiments are under way on tool steels which will not draw appreciably at temperatures of 800 to 1200 F. All these aforementioned tests for 52100 steel will have to be duplicated using these high temperature steels. These tests, however, will have to be delayed until high temperature steels can be produced free enough from inclusions, etc., to eliminate premature bearing failure due to these adverse features. At the present time tests have been started on high temperature vacuum melted steels which appear to be free from defects. However, since tests have just been started there is nothing to report as yet.

LUBRICATION: The greatest retarding factor in operating bearings at high speed and relatively high temperature is lubrication. The type of lubrication may be divided into two general categories, namely: oil and grease. With the use of oil lubrication such as jet or mist, it is possible to operate ball bearings of proper design and perfection at speeds in excess of 15,000 inner race surface feet per minute and in relatively high ambient temperatures as the oil carries away generated or ambient temperature effect from the bearing and so reduces the drawing effect on the bearing steel. However, present-day design, due to its compact nature, often does not easily permit the use of auxiliary oiling systems which means that bearings must be lubricated with compact, non-circulating systems. This, of course, means that bearings will operate at ambient or self-generated temperatures and both bearing and luricant must withstand these high operating temperatures.

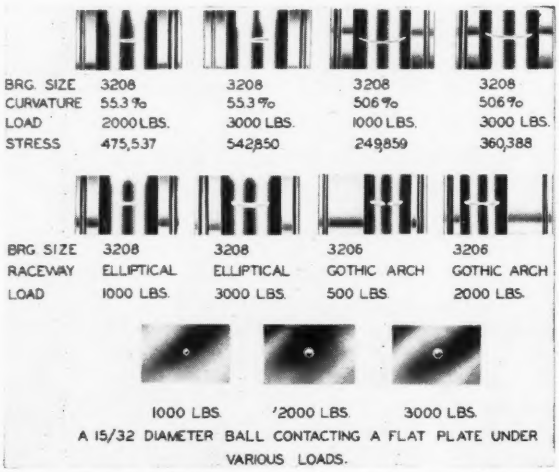
BRG. SIZE 3208 3208 3208 3208
CURVATURE 55.3% 55.3% 506% 506%
LOAD 2000 LBS. 3000 LBS. 1000 LBS. 3000 LBS.
STRESS 475,537 542,850 249,859 360,388
BRG SIZE 3208 3208 3206 3206
RACEWAY ELLIPTICAL ELLIPTICAL GOTHIC ARCH GOTHIC ARCH
LOAD 1000 LBS. 3000 LBS. 500 LBS. 2000 LBS.
1000 LBS. 2000 LBS. 3000 LBS.
A 15/32 DIAMETER BALL CONTACTING A FLAT PLATE UNDER VARIOUS LOADS.

Fig. 4 Pressure ellipses resulting from various specified loads and raceway characteristics.

In a ball bearing there are two locations which must be lubricated, namely: the stressed area between the balls and races and between the balls and retainer. Contrary to the conception of most laymen, the contacting area between a ball and race is not a point contact but rather a sizeable ellipse-shaped area. These areas can be made to take many shapes by varying the shape of race or conformity of race to ball, that is, a close conformity of race to ball under a given loading will

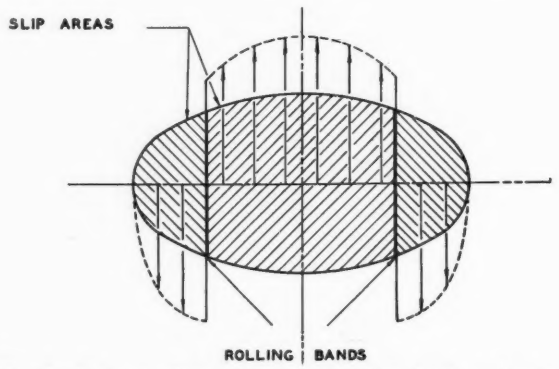

Fig. 5 Pressure ellipse showing true rolling bands and areas of slip.

make an ellipse having a large major axis relative to the minor axis, and, as the conformity is opened up (decreased) on a circular race, the major axis diminishes and the minor axis increases. For a circular race the bearing capacity decreases as the conformity is decreased. Self-induced temperature decreases as conformity decreases for a given ball load. By making non-circular races the contact areas can be completely changed. A representative group of contact areas with notations as to the conditions under which they were made is shown in Fig. 4.

Also, contrary to the belief of the average lay-

(Continued on page 102)

CONTAMINATION OF SURFACE WATERS BY WASTE OILS*

by D. E. Bloodgood
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Lafayette, Ind.

Prof. Bloodgood received his degree from the Univ. of Wisconsin in 1926. Upon graduation he was employed by the Milwaukee Sewerage Comm. as Laboratory Ass't., later as Ass't. Research Chemist; by the Indianapolis Sanitary Dist. in 1929 as Sanitary Engr., later as Manager of a disposal plant; by Purdue Univ. in 1943 as Assoc. Prof. of Sanitary Engrg., in 1947 as Prof., Sanitary Engrg. He has been Vice-Chairman of the Indiana State Board of Health since 1949, and is a member of the Amer. Water Works Assn., ASCE, Am. & Ind. Pub. Health Assns., Fed. Sewage Works Assns., Central States Sewage Works Assn., Ind. Soc. Professional Engrs., Ind. Izaak Walton League, Ind. Acad. Sci., Purdue Ind. Waste Conf., Sigma Pi.

ABSTRACT: This paper points out that the extensive use of lubricating oils results in a tremendous quantity of spent oil that must be disposed of. The present methods of disposal, good and objectionable, are discussed at some length. The detrimental effects of oil on sewage treatment methods are described. A review of methods for the elimination of excessive wasting of usable lubricants is given. The present methods of oil water separation by floatation are presented, and their effectiveness discussed. The factors influencing the formations of emulsions are described. The chemical methods of breaking emulsions are presented and their effectiveness discussed. A brief presentation of the present research in determining the oil capacities of certain chemical flocs is presented.

OIL WASTES IN SURFACE WATERS: In 1947 there were 57,765,000 barrels of lubricating oil produced in the United States according to the 1949 Statistical Abstracts of the U. S. Department of Commerce. This is a small quantity as compared with the amount of gasoline refined and used each year but lubricating oil, unlike gasoline, is not all converted into gases when it is no longer of service. Much of the lubricating oil is dripped over the surface of the earth or is vaporized or burned as it serves its purpose as a coolant or lubricant.

It has been the policy of humans in the years gone by to discard their unwanted materials into the natural drainage systems where they would be flushed away by the flowing streams or the rains. Some of the waste materials were dissolved in the water and, if there were not too large a quantity in proportion to the flow of water in the stream, there would be little or no complaint about it. Some of the other wastes discharged were present as solids that when wetted became suspended in the water. If the particles were fine enough so that they stayed suspended and there were not too many of them, few complaints were made about them. Oil, being the material that it is, does not combine or readily mix with water and surprisingly little oil can contaminate a relatively large body of water.

*Sponsored by the Technical Committee on Lubricant Reclamation & Disposal and presented at the 7th ASLE Annual Meeting, Cleveland, April 8, 1952.

It has been reported that one barrel of oil will give a characteristic sheen to one square mile of water surface. The thickness of such an oil sheen is only .000 003 inches but the oil film it produces can be readily seen. A barrel of almost any other substance would hardly be found if the water had any depth at all. It would take only 0.2% of all of the lubricating oil produced in the United States to give a sheen to all of the inland waters of the country, including the Great Lakes. Because oil can be so readily seen on water it leaves the impression that there may be a considerable quantity present. However as a matter of fact, if one barrel of oil could be mixed with a square mile of water that was twenty feet deep, there would be less than 0.01 p.p.m. of oil in the water. This is an extremely small quantity and if present in the form of some of the more toxic materials it would not be objectionable. Of course, the oil on the surface is nearly one hundred per cent of oil and is therefore objectionable.

Quantities of iridescent oil may be calculated from estimated areas and thickness more accurately than they can be determined by sampling and testing. Iridescent oil rarely will amount to as much as 5 p.p.m. and in most cases, considerably less than this amount, if the stream or body of water is two or more feet deep. Table I gives some idea as to the appearance of oil films of different thicknesses.

OBJECTIONS TO OIL WASTES: Much of the water used in this country comes from surface water sources. However, if the only objection to oil in water were that it could be seen, there would still be many complaints about it because very small quantities impart an objectionable taste that is very difficult to remove by even the best of modern water treatment methods and equipment. Furthermore, the small quantities of oil previously mentioned are enough to prevent the use of the body of water for recreational purposes. Also, oil in streams is apt to impart objectionable tastes to the aquatic life present. For example down on the Ohio River at the present time there are statements made by scientific people that the quantities of oil getting into the stream from the oil barges are sufficient to taint the flesh of river fish.

It should not be inferred that all waste oils are directly or intentionally discharged to bodies of water. In some instances waste oils are discharged to sewage systems and if there is a sewage treatment plant and the quantity of oil relatively small the oils may be caught and removed. However oils are difficult and costly to handle with sewage.

Once oils have become mixed (used figuratively) with water it is not easy to separate them by skimming. Because of the inert nature of mineral oils they are not decomposed by the biologic processes most commonly used by municipalities. Oil that rises in sewage treatment sedimentation tanks carries to the surface with it organic solids that would otherwise be removed by sedimentation and other processes but because they are combined with the oil they make the disposal of the skimmed oil very difficult. Further the skimmed oil is so intermixed with debris and water that it is almost impossible to burn it with known equipment. Speaking as a sewage plant operater, the writer will say that if the problem were merely one of skimming the oil from settling tanks and the disposal of the same, there would probably not be many complaints, unfortunately the oil coats the suspended solids and is carried through primary settling into secondary treatment such as activated sludge and trickling filter units, making it almost impossible for the micro-organisms to work on the organic solids and convert them in the normal way.

The question will no doubt be asked, "What is the maximum concentration of lubricating oil that can be handled in a biological sewage treatment plant?" In answering, it can be said that it is doubtful whether there is anyone who knows what the maximum allowable concentration is but it is obvious that the lower the concentration, the less difficulty there will be in treating the sewage and of course, the cost of treatment will be lower.

In the activated sludge treatment process the oils seem to coat the sludge floc. The sludge then often turns black indicating that it is difficult or impossible to get the oxygen from the diffused air to the aerobic organisms in the sludge. Unless these organisms are supplied at all times with enough oxygen they are not effective in the treatment of the sewage.

Quantities of oil greater than 100 p.p.m. on the basis of all sewage received at a sewage treatment plant can be expected to give considerable trouble. Quantities of oil skimmed from primary sedimentation tanks are sometimes discharged to separate sludge digestion tanks where the oil accumulates at the top of the tank forming, along with certain lighter solids, a very thick mat of scum. For example at Crawfordsville, Indiana, mats several feet in thickness have developed and there is no easy way of removing the oil from the top of the tanks where it remains to interfere with the liberation of gas from the decomposing sewage solids.

METHODS FOR OIL WASTE HANDLING: Some of the noisy complaints in the years past have come from the vicinity of oil refineries where the oil losses, though small percentagewise, have amounted to rather large quantities. Many of the refineries have started their corrective measures after first making a complete survey of their plants, thereby determining where the actual oil losses occur. When the points of loss have been located, redesign of the sewer systems has been undertaken with the result that in most cases three entirely separate sewer systems have been planned and installed. One system is designed to carry uncontaminated cooling and drainage water, another to carry the contaminated process water, and the third to carry the sanitary sewage. This procedure reduces the volume of water that has to be treated prior to its discharge to the municipal sewers or the receiving stream and simplifies treatment. For example, Morgan[1] has reported that the sanitary sewage interferes with the treatment of the refinery waste waters. Many of the large as well as small refineries of today have completed the installation of these separate sewer systems. Fowler[2] has given in some detail the program carried out by the Sinclair Refining Co. at their East Chicago, Ind., refinery.

Approx. Thickness of Film of Oil - Inches	Appearance	Approx. Quantity Gallons of Oil for Film 1 Sq.Mi. in Area Gallons
.000 001 5	Barely visible under most favorable light conditions.	25
.000 003	Visible as silvery sheen on surface of water.	50
.000 006	First trace of color may be observed.	100
.000 012	Bright bands of color are visible.	200
.000 040	Color begins to turn dull.	666
.000 080	Colors are much darker.	1332

Table I—Film thickness, appearance & quantity of oil on water surfaces.

Frequent sampling of the waste waters containing oil will make it possible to keep a close check on the losses from a particular plant. One report recently read states that samples are taken three times per week. Such samples will give only a general idea of the character of the waste waters and are not likely to be of great value in proving the good quality of a plant effluent or be of much use by management in keeping down uneconomical plant losses. In some instances it has been only the spills that have caused the difficulties so that their elimination has been all that was necessary to treat satisfactorily the oil polluted waste waters.

METHODS OF OIL-WASTE TREATMENT: The intensive work on the API Separator has resulted in a piece of equipment that has proved to be very satisfactory in materially reducing the oil content of waste waters. Giles[3] in reporting on the API separator operation at the Standard Oil Co. (Ind.), Whiting Plant, said that the oil losses were cut 68 to 80 per cent upon installation of the separators.

The concentration of oil in the effluent varied considerably as demonstrated by the results obtained, during one summer month, in the range of 7 to 103 ppm. Thus it is apparent that, if it is necessary to maintain consistently low concentrations of oil in the effluent additional, treatment would be required. Efforts have been made to reduce the oil remaining after A.P.I. separator treatment by using chemical flocculation. Austin and Vause[4] have reported on the pilot plant studies at the Standard Oil Co. Whiting Plant and their reported results show that by chemical flocculation they are able to reduce the oil concentration from 60 ppm. to 5 ppm. In order to accomplish this reduction it was neccessary to use 25 ppm. of ferrous sulfate, 10 ppm. of activated silica and 150 ppm. of dolomitic lime. This is 185 ppm. of chemicals for the removal of 55 ppm. of oil!

Not all of the waste oils will separate readily from the waters in which they are mixed. Sometimes the oils are emulsified oils and in this state are much more difficult to remove. Such oils may

result from processing in refineries or they may be purposely made to serve as lubricating coolants used in metal processing plants. Weston[5] in discussing oil wastes says that these emulsions are very stable and hard to break. Therefore, if it is possible, spent emulsions should not be diluted by discharging them with other waste waters. Where the emulsions are used as lubricants they should be collected separately and the emulsions broken and the oil released skimmed from them. It is sometimes possible to recover spent lubricating emulsions and purify and sweeten them prior to reuse. This procedure certainly reduces the magnitude of the oil waste problem and has the further direct advantage of reducing the volume of cutting oil which must be purchased. Barr[6] reports that it is possible to save materially on the quantity of oil lost from the machining and heat treating departments of a metal working plant by reusing the cutting oil and by installing oil removal equipment at the heat treating furnaces.

Walker[7] describes a two stage system for handling contaminated soluble-oil mixtures. Partial emulsion breaking and conditioning is done in the first stage. In the second stage the suspended matter is precipitated and clarification of the effluent takes place. In one plant he states that a 3000 ppm. oil waste can be reduced to only a trace and in another a waste with 4000 ppm. of oil can be treated so that it contains but 20 ppm. or less of oil. In the first stage alum is used as the chemical and in the second stage lime or sodium hydroxide and sulphuric acid have been used. The precipitated sludge in these two cases is disposed of by ponding or is acidified in a closed system with the recovery of the alum.

Griffith[8] has described a two-lagoon system for handling the wastes from a metal working plant. In the first lagoon, with a detention of about two days, the insoluble oil and the emulsified oil wastes that contain between 735 to 1800 ppm. total oil are reduced to an average figure of 144 ppm. In the second lagoon the detention time is about twenty-five days and the effluent contains 7 ppm. of oil.

LEGAL CONTROLS ON OIL WASTE DISCHARGE: Some of the objections to the discharge of waste oils have been presented and a number of methods used for the elimination of them have been outlined. Attention will now be turned to some of the regulations intended to keep under control the discharge of oil bearing wastes into sewers, sewage treatment works and receiving streams or other bodies of water.

That there are controls over industrial waste discharges, there is no doubt, and they range in jurisdiction from municipalities to international commissions. There is the International Joint Commission of the United States and Canada; there is the Federal Water Pollution Control Act of 1948; there are numerous compacts between states, such as the Ohio River Valley Water Sanitation Commission; practically all states have pollution control legislation; there are regulations established for certain districts that include more than one municipality, such as the Chicago Sanitary District; there are many cities in the country that have one or more ordinances controlling the discharge of industrial wastes. It would at first seem that it is not necessary to have so many controlling agencies if the basic rule of common law is followed, that is, "each riparian proprietor has the right to have a stream come down to him with its quality unimpaired and with its quantity undiminished," but there must be modification of the common law and these modifications are brought about by the controls established by the regulating bodies at the various levels of government. Legislation at the various levals should be so written that it will control groups of the next lower level of government. This has been found to be difficult inasmuch as the requirements for the higher level (the greater number) may of necessity be more stringent than the smaller governmental unit.

The regulations established have been largely guided by the rulings of certain courts. As an illustration, the Virginia Supreme Court of Appeals in giving a decision on a stream pollution case (McKinney vs. Trustees of Emory and Henry College 86 S.E., Rep. 115) said, "Any pollution of a stream which is sufficient to foul the water or to impair its value for the ordinary purposes of life, or anything which renders the water less wholesome than when in its natural state, or which renders it offensive to taste or smell, or which is naturally calculated to excite disgust in those using the water will constitute a nuisance which a court of equity will enjoin or for which the lower riparian owner injured thereby is entitled to redress." A decision of this kind does not set out the parts per million of any objectionable substance that may be considered a nuisance so it is necessary for the controlling agency, having jurisdiction to establish reasonable limits. It should be remembered that regulations should be enforced so as to eliminate court actions that otherwise would be carried out to prove that damage had been done.

If some regulation establishes that a treated industrial waste effluent cannot contain more than 10 ppm. of oil, those who are responsible for the regulation should be firmly convinced in their own minds that a greater concentration than this would result in conditions which, if presented in court as evidence, would convince the court that damage had been done. It would seem that this should be the broad view taken by all parties thereby minimizing arguments over effluent quality, stream standards, and classification of streams. It would, therefore, be unreasonable to expect regulatory agencies to establish narrow and specific regulations that were applicable to everyone. If this type of regulation is demanded by industry it will result in the establishment of controls with ample factors of safety and the over-all result will be uneconomical. In all events, the cost of treatment of industrial wastes must be kept at a reasonable level.

FUNDAMENTALS IN OIL WASTE TREATMENT: One of the ways of finding possibilities for the reduction of processing costs is to acquire a better knowledge of the fundamentals of the particular process. It has been pointed out that the chemical flocculation of oil wastes has proved to be successful. However, the reasons why are not too clearly understood. The process of clarification might be explained by one or more of the following theories: (1) Adsorption of the oil on the floc surface, (2) Entrapment of the oil as the floc is

formed, (3) Neutralization of the electric charge on the oil droplet by an opposite charge on the formed floc.

Fundamental studies[9] have been under way at Purdue University for the past several months in an effort to learn the capacity of chemical flocs in the removal of oils from oil water emulsions.

A standard emulsion was used in the studies and the oil particles were believed to remain in a stable state of emulsification because of their extremely small size and the electric charge on each oil particle as no emulsifying agent was used. The flocculating chemicals used were ferric chloride and lime. By forming a floc in distilled water and then adding emulsified oil it was possible to determine the amount of oil adsorbed per mass of adsorbing agent. The amount adsorbed was found to be proportional to the final concentration of oil. Data taken showed that the removal of the oil was not a true adsorption and may be considered to be absorption when the preformed floc is used. In similar tests where the floc was formed in the presence of the emulsion, all of the oil is removed. In these tests a thin film of oil appeared on the water surface of the more concentrated samples. It might be, however, that the clarification effect by the floc formed in the emulsion took place at the instant of formation of the very small particles that may have a high absorptive capacity and as they agglomerate to form larger particles they entrap the oil. It is possible that more complete studies along these particular lines may result in more effective and less expensive removal of oil from waste waters.

SUMMARY: Though there are great quantities of oil lost to surface waters in the United States there is every reason to believe that with separate sewering, pre-treatment, and other devices for reducing the quantity of oil, it is possible to eliminate objections that have been raised in the past. There are methods of treatment that will give the variations in effluent required by any regulatory agency for any situation. Though the methods of treatment are known only a complete understanding of the fundamental processes will permit increases in effectiveness and reductions in cost of operation.

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[3]R. N. Giles: Oil-Water Separation. Proceedings, Sixth Purdue Industrial Waste Conf., Engrg. Ext. Dept., Series No. 76, 1951.

[4]R. J. Austin & E. H. Vause: Chemical Flocculation of Refinery Waste Water. Proceedings, Sixth Purdue Industrial Waste Conf., Engrg. Ext. Dept., Series No. 76, 1951, p. 272.

[5]R. F. Weston: The Waste Disposal & Utilization Problems of the Petroleum Industry. Proceedings, First Purdue Industrial Waste Conf., 1944.

[6]J. A. Barr: Reclamation of Oil in a Large Industry. Proceedings, Fourth Purdue Industrial Waste Conf., Engrg. Ext. Dept., Series No. 68.

[7]D. J. Walker: Treatment for Disposal of Spent & Contaminated Soluble-Oil Mixtures. Proceedings, Fifth Purdue Industrial Waste Conf., Engrg. Ext. Dept., Series No. 72, 1949, p. 63.

[8]C. R. Griffith: Purification of Wastes in a Metalworking Plant by Lagooning. Proceedings, Sixth Purdue Industrial Waste Conf., Engrg. Ext. Dept., Series No. 76, 1951, p. 421.

[9]Financed by the National Lime Assoc.

COMMENTARY by R. J. Austin, Standard Oil Co., Whiting, Ind.: Prof. Bloodgood has presented an excellent paper on a subject of rather broad scope. He has, nevertheless, illustrated some of the basic elements of the problems resulting from the disposal of waste oils. The difficulties resulting from lubricating oils being discharged to sanitary sewage treatment plants are discussed and the suggestion is made that 100 ppm. of oil in the sewage may be the critical concentration where biological processes are in use. Gravity-type separation, lagooning, and chemical flocculation are discussed as means of removing oils from water.

In his discussion of 'Oil Wastes in Water', Prof. Bloodgood has raised that old question of long standing—"What happens to oil that gets into streams, lakes, etc.?" In relatively recent years, it has become recognized that these oils are altered by biological processes. The literature, however, contains little, if any, information that indicates the course of such reactions or of the end products. It is quite likely that specific information along these lines will be available in a few years. In 1950, an article appeared in the literature (Bacterial Oxidation of Oil and its Migration in Natural Water Reservoirs by A. A. Voroshilova and E. V. Dianova, Mikrobiologiya, Volume 19, pages 203-210, 1950) which describes a study made in Russia to determine the fate of oils discharged to Moscow River. In brief the authors state that most of the hydro carbons composing petroleum can be utilized by bacteria. Oil when discharged to a body of water for the most part floats on the surface, only a minor portion being dissolved in the water. The oxidation of the oil by bacteria is a two-stage oxidation involving both aerobic and anaerobic micro-organisms. The data show that the bacterial population in the water immediately beneath the oil film increased rapidly. Depletion of oxygen in this region and increase in bacterial population indicated that aerobic oxidation was in progress. Specific gravity of the oil in the film increased, due to evaporation of the light ends and formation of heavier reaction products, resulting in the oil sinking to the bottom of the stream. Settling of the oil was facilitated by the presence of suspended matter in the river water. At the bottom of the stream where oxygen was known to be absent, anaerobic organisms further oxidized the oil resulting in liberation of methane and carbon dioxide. The liberation of these gases from the bottom of the stream caused some of the oil to be carried to the surface of the water where aerobic oxidation of the oil was again started. Data reported in this article were obtained from both laboratory studies and investigations conducted on the river. Studies are in progress in a number of industrial establishments and at some universities on the problem of treating oil-bearing industrial wastes by biological processes, namely the activated sludge treatment process and trickling filters. The application of the biological processes to industrial waste treatment, in general, is not primarily for the purpose of removing oil, however, its removal is effected in both methods to a relatively high degree.

Coverage of the great variety of problems associated with the disposition of spent lubricating oil is beyond the scope of this discussion. Prof. Bloodgood has stated that about 58,000,000 bbls. of lubricating oil are manufactured each year. This amount of lubricating oil is composed of several hundred different products. These oils are used in amounts ranging from a few drops up to several hundred gallons in some instances. Recovery of used lubricating oils, in order to prevent their becoming a pollution problem, is practiced on a wider scale than is generally recognized. As long ago as 1925, it was common practice to collect crankcase drainings at service stations and use them as fuel oil. This type of recovery is common practice today in many machine shops and in most large industrial plants. Recovery for reuse is practiced on a much smaller scale. This reduced scale is due to such economic considerations as protection of expensive machinery and the imbalance that exists in costs between purchasing a new product and reprocessing in relatively small quantities, a reclaimed product. The oil industry has assisted cutting oil users in the problems of resolving these emulsions for disposition and in inhibiting bacterial action that causes early failure of the oil without loss in cutting oil business.

The frequency of sampling waste water streams was mentioned by Prof. Bloodgood. I assume that he was thinking of large establishments when he suggests that three times a week is not often enough. This is a controversial subject and one that has to be worked out by industrialists and the State

(Continued on page 99)

Annual Meeting Authors

Authors of papers to be presented at the 8th ASLE Annual Meeting, Hotel Statler, Boston, April 13-14-15.

Abstracts of papers are included in this issue, except for those arriving too late to meet publication deadlines.

W. J. Anderson

A. E. Baker

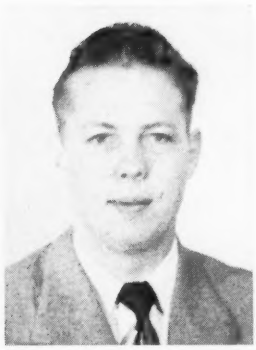
E. R. Booser

V. N. Borsoff

P. B. Burgess

W. E. Campbell

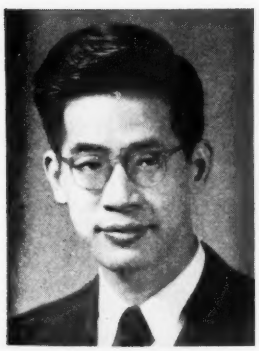
E. C. Crankshaw



A. O. DeHart

B. J. Dempsey

R. H. DuBois



I-Ming Feng

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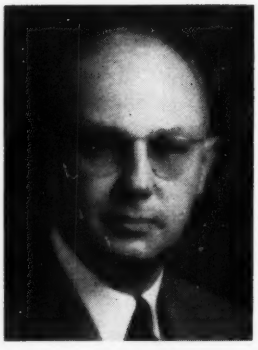
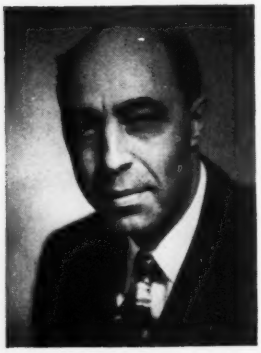


A. B. Myler

J. D. Pigott



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K. P. Powers

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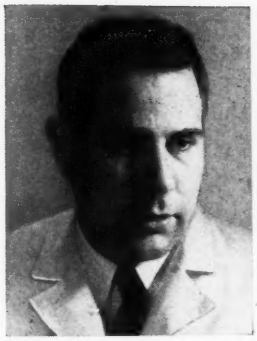
R. G. Rightmire



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Annual Meeting Abstracts

The following abstracts of papers to be presented at the 1953 ASLE Annual Meeting, Hotel Statler, Boston, April 13-14-15, are published herewith for general information and to stimulate discussion at the meeting. They do not necessarily represent the final opinions of the authors and are subject to revision when the complete papers are published.

A METHOD OF EVALUATING CUTTING OILS ON A LATHE BY MEANS OF A TOOL BLADE WEAR TEST

by L. C. Hayes, Thompson Products, Inc.
E. J. R. Hudec, Case Inst.

This paper covers a new laboratory lathe test method to evaluate the cooling and lubricating ability of a cutting fluid. A tool blade, made of any desired tool bit material, is rubbed against a revolving work piece immediately behind a cutting tool so that a nascent surface is encountered. It is felt that by this means the same surface rubbing conditions are encountered on the tool blade as those on a tool bit in metal cutting.

The tests are made under cutting conditions generally used for the tool bit material and work material involved. The tool blade is mounted in a lever mechanism and a uniformly increasing load is applied to it throughout each test run. The amount of wear on the tool blade is a measure of the cutting fluids lubricating and cooling ability. The cutting fluid is applied in two different ways: (1) in which the surface is just wet with fluid to measure the lubricating effect and (2) the surface is flooded and two auxiliary streams of coolant are played on each side of the tool blade to measure both the lubricating and cooling effect.

A NEW APPARATUS FOR RAPID FATIGUE EVALUATION OF MATERIALS FOR ROLLING CONTACT BEARINGS

by E. F. Macks
NACA Lewis Flight Prop. Lab.

A new apparatus of unusual simplicity is described which permits evaluation of the fatigue life of balls and race ways in hours instead of months. Precise loads at exceptionally high frequencies over a wide range of variables are possible. Stress frequencies to 10 million per hour and calculated Hertz stresses to 700,000 psi have been obtained. Rolling contact under elastic deformation provides surface compression, and tangential stresses, and subsurface shear stresses which induce fatigue failures of the type occurring in rolling contact bearings under radial or combined loads.

A NEW THEORY OF METAL TRANSFER & WEAR

by I-Ming Feng
Mass. Inst. of Tech.

Given in this paper is a discussion of a newly developed theory of metal transfer and wear, which includes the mechanical interlocking effect of plastic roughening of contacting interface as the primary cause and the adhesion or diffusion process induced by temperature flash during breakage as the secondary cause of metal transfer and wear.

AIR BEARING STUDIES AT NORMAL & ELEVATED TEMPERATURES

by J. D. Pigott & E. F. Macks
NACA Lewis Flight Prop. Lab.

Experimental studies were made of an externally pressurized, parallel surface, non-rotating, air thrust bearing at temperatures up to 1000 F., and loads up to 200 pounds. Self-alignment was accomplished through the use of recesses in the bearing surface which were pressurized through individual capillary resistance tubes which were connected to a common manifold. Theoretical expressions describing the radial flow through the bearing and the air flow through the capillary tubes are presented. Experimental and theoretical values are compared, and the increase in load capacity of an air bearing with an increase in temperature is discussed. Critical design factors and design calculations are considered. An extensive bibliography of past work on air bearings is included.

BALL PATH GEOMETRY—AN INDEX TO TYPE OF LOAD

by H. N. Kaufman
Westinghouse Research Labs.

It is the purpose of this paper to indicate to the non-specialist in ball bearing problems, how the ball path geometry may be used as an index to the type of load in determining the probable causes of ball bearing failure.

As it is difficult to show these ball paths clearly by photography, use has been made of the pictorial drawing for this purpose.

BEARING FAILURE IDENTIFICATION WITH PARTICULAR EMPHASIS ON LUBRICATION

by B. J. Dempsey
New Departure Div., GMC

Although considerable material has been published on the damage done to bearings by overload, misalignment, mishandling, etc., there is a scarcity of material on failures with regard to lubrication, retainer wear and retainer breakage and the like. The paper will cover some of these cases.

A portable noise test unit which can be used to illustrate the characteristic noises caused by dirt, brinelling, lack of lubricant, etc., will be demonstrated.

CAUSES OF ANTI-FRICTION BEARING FAILURES AS AN AID IN PREVENTION

by H. O. Walp
S. K. F. Industries

Description with photographic illustrations of the more prevalent types of anti-friction bearing failures. Most failures are, to a large degree, preventable by proper bearing selection for the application, sufficient care in handling to prevent mechanical damage, proper mounting, cleanliness and adequate lubrication and maintenance.

DESIGN & SERVICE REQUIREMENTS DICTATE THE CHARACTERS OF OIL ADDITIVES

by E. C. Knowles & G. R. Furman
The Texas Co.

Originally it was the function of a lubricating oil to provide a film of liquid to separate surfaces in relative motion, whether in a plane, or rotating or reciprocating. New functions are now provided by the use of oil additives so that rusting and corrosion are inhibited, oxidation of the lubricant is controlled, chemical films are produced to stop welding or galling, combustion soot is kept dispersed, foaming is kept at a safe level, for examples. These additives of necessity impart certain characteristics to the physical and chemical properties of the lubricants, separate and apart from those advertised. These concurrent effects are well known and carefully studied by the oil development engineer or scientist. They are not always too well understood or recognized by the user. This paper designs to raise the curtain on some of these side-effects in the interest of a better over-all understanding. Several examples of the need for additive fortification are cited along with other examples of the effect of this fortification on some of the usual or well-recognized tests made in the laboratory on lubricating oils—tests which are usually only for identification and do not necessarily control quality.

DIAGNOSING NEEDLE BEARING TROUBLES BY VISUAL INSPECTION

by A. B. Williamson
McGill Mfg. Co.

Various types of roller bearings identified by the trade as "Needle Bearings" will be illustrated and the types of applications to which they are best suited will be discussed. The appearance of needle bearing failures due to various causes will be illustrated and described.

ELECTROGRAPHIC SPOT TESTING OF BEARING SURFACES

by A. E. Roach & A. O. DeHart
Research Labs. Div., GMC

Electrographic spot testing is a simple, rapid, and reliable means of studying bearing surface characteristics. The test is non-destructive and gives a permanent record. Some applications discussed in the paper are: identity of embedded particles, porosity of plated overlays, segregation of bearing alloys, and metal transfer and wear. The paper describes some typical spot testing procedures and apparatus for testing bearings.

EVALUATION OF LUBRICANTS FOR THE COLD ROLLING OF BRASS

by J. W. Johnson
Atlantic Refining Co.

As a result of a survey of the brass industry in New England in the fall of 1949 which revealed that there was a need

for more basic information on the performance of brass rolling lubricants, an experimental study was undertaken on the evaluation of brass rolling lubricants based on an actual brass rolling operation. The Bridgeport Brass Co. became interested in the program and offered the services of their organization and the use of a rolling mill to conduct the investigation. This paper is a discussion of that investigation and some of the initial results.

In considering the various requirements of a lubricant the reduction in external friction was obviously the most important. This factor required that the method of evaluation simulate actual commercial rolling conditions as closely as possible. The method of evaluating lubricants was essentially by a measurement of the coefficient of friction on a rolling mill with all rolling variables except reduction in thickness and pressure either held constant or varied at equal rates.

In obtaining a simple and reliable method of comparing the friction-reducing properties of lubricants, the expression derived by Stone and Greenberger of United Engineering & Foundry Co. was used.

A summary of the most interesting test results on various lubricants includes: (1) Effect of viscosity of lubricant, (2) Effect of oilness and extreme pressure additives, (3) Effect of type of base stocks, (4) Effect of roll surface finish.

FRICTION & BOUNDARY LUBRICATION
by A. C. West
Calif. Research Corp.

On the basis of a review and analysis of the extensive published literature on the subject of friction, the mechanism of sliding friction is discussed as applied to metal surfaces under conditions of both dry metallic contact and boundary lubrication. Although there are other plausible theories of friction, there is much evidence presented in the literature in support of a theory which explains friction as the force required to rupture minute "bridges" formed between contacting asperities of sliding surfaces. The function of a boundary lubricant is to reduce the strength and number of these bridges.

MECHANISMS OF SLEEVE BEARING FAILURES
by P. B. Burgess
Standard Oil Co. (Ind.)

A system of visual determination of the most probable mechanisms of sleeve bearing failures is explained by means of an illustrated flow sheet. With the aid of a magnifying glass and a steel probe, most failures may be classified by the mechanism of fatigue, bond failure, dirt damage, sweating, and corrosion.

Each mechanism is discussed and illustrated; the steps in the visual examination are shown by micrographs. Although common causes of difficulty are cited, no attempt is made to indicate specific causes of failure.

MODERN TRENDS IN THE USE OF CUTTING OILS
by A. B. Myler
Sun Oil Co.

This paper discusses the cutting oils, both emulsifying and non-emulsifying, which are being used today in modern metalworking shops. It covers the growing use of emulsions on automatic screw machines and explains what precautions and controls are necessary for their successful application. It also talks about heavy duty emulsifying oils, what they are, and for what purposes they have been found to be particularly adapted. This paper also discusses the trend in non-emulsifying cutting oils away from the heavily compounded dark-colored oils to the lightly compounded transparent oils. This trend has been made possible by newly developed additives which give these modern cutting oils the ability to keep pace with the ever-increasing demand for greater production.

OPEN GEAR LUBRICATION
by H. W. Winkler
The Brooks Oil Co.

This paper is an endeavor to explain the physical and chemical characteristics of the types of products used in the lubrication of open gears, as employed in industry. These physical and chemical characteristics govern the service for which a lubricant can be used and also the method of application. Reasons are given for the proper handling and storage of various gear lubricants. To insure longer life for both the lubricant and the gear, consideration is given to methods of protecting the lubricant from contamination while in service.

SCORING & WEAR OF SPUR GEARS
by V. N. Borsoff & F. C. Younger
Shell Develop. Co.

Two theories exist for the state of lubrication of meshing gear teeth: one assumes that hydrodynamic forces are negligible and that thin film boundary lubrication only is possible; the other attributes the load carrying capacity of gears to the existence of a thick oil film separating the working surfaces. In previous work the authors have shown the results of gear tests in which the microscopic observation of the surfaces indicated that non-reactive mineral oils always operate with thick film lubrication, and therefore without wear as long as no scoring occurs.

Microscopic inspection of surfaces, and measuring wear by weighing the gears, were not quite satisfactory to demonstrate reliably the absence of surface contact which would be expected if lubrication is by a thick film. These techniques were therefore supplemented by making one gear radioactive and measuring wear by the radioactivity of the oil. Metal transfer was observed by radiographing the tooth surfaces of the inactive gear. The results confirm the complete separation of the mating surfaces in the thick film region with non-reactive as well as E. P. agent containing oils. When the Hp-ZN curve is reached, metal transfer, wear and visible scoring start simultaneously with non-reactive oils. If an E. P. agent is present metal transfer also begins there, but no visual scoring occurs and wear is negligible, indicating satisfactory boundary lubrication. A further increase in load produced increased metal transfer and an increased steady rate of wear.

SOLID LUBRICANTS
by W. E. Campbell
Bell Telephone Labs.

A solid lubricant is defined as a solid interposed between two relatively moving rubbing solids to reduce friction and wear, so that the friction is all solid friction. The modern theory of solid friction is therefore reviewed and the basic characteristics conferring good wear reducing behavior on a solid lubricant are deduced from it. Other physical and chemical properties of a solid lubricant which may be desirable under certain circumstances are discussed.

A solid lubricant is only needed where the use of fluid or semi-fluid lubricants is impossible, undesirable or ineffective. It will not in general therefore substitute for a satisfactory fluid or semi-fluid lubricant although it may supplement it.

Solid lubricants are classified in five groups: (1) Solids having a laminar structure, (2) Chemical conversion coatings, (3) Soaps, fats or waxes, (4) Soft metal films, (5) Polymer films. The characteristics of each class are discussed in relation to the ideal deduced from theory.

Several important general situations calling for use of solid lubricants are given and examples in each discussed with illustrations. Methods of compounding and application are discussed. The direction of future research and development is indicated.

SOME LUBRICATION PROBLEMS ON ROLLER BEARINGS AND THEIR SOLUTION
by R. H. DuBois
Bower Roller Brng. Co.

Lubricating a tapered roller bearing is normally a very easy and straightforward procedure. Application techniques often impose hardships on the bearings which makes lubrication a critical item. The main problem is to get lubrication to the right place on the bearing. Lubricating engineers should participate in design, as well as the selection of a particular oil or grease for new products.

Grease vs. oil lubrication argument continues. Oil will promote more marginal bearing operation, but ceiling problems are further complicated. The fact that some grease tends to retain moisture has caused considerable trouble in truck wheel bearings.

The problem of removing heat from bearings is paramount. Circulation of lubricant is important, and an item which lubricating engineers should always consider.

Air craft cylindrical roller bearings have posed tremendous lubricating problems. The method of getting oil to critical surfaces has demanded new and unusual oiling techniques.

Skin temperatures of retainers, races and rollers may be extremely high, due to skidding attendant with lightly loaded high speed roller bearings. Considerable experimenting and development must be done by both bearing manufacturers and lubrication engineers.

SOME VISCOSITY-SHEAR CHARACTERISTICS OF LUBRICANTS
by E. E. Klaus & M. R. Fenske

Penn State Univ.

Linear type polymers are important additives used in formulating improved lubricants of both petroleum and synthetic origin. Usually these materials are employed in concentrations of about 0.5 to 10 weight per cent. One of the most important general properties of these polymers is that of improving the viscosity-temperature characteristics of oils, i.e., making oils have less viscosity change with temperature.

Solutions of these polymers have two important characteristics not found in conventional mineral oils. Both of these are brought about by shearing stresses. In one case there is a permanent loss in viscosity. This results when high turbulence and severe throttling are imposed on the oil for long periods of time. The greater is this type of shear, the greater the loss in viscosity. The other effect is a temporary and reversible viscosity loss. This occurs when oil films are subjected to high shear rates in streamline flow. This effect is proportional to the rate of shear; it appears and disappears reversibly, depending upon the magnitude of the shearing stress.

These two effects for three types of polymers are illustrated by laboratory data, and are related to practical applications involving pumps, orifices, relief valves, gears and bearings. The oils include hydraulic fluids, gear and crankcase oils, and gas turbine lubricants.

TEXTILE MACHINERY LUBRICATION FROM MANAGEMENT POINT OF VIEW

by R. M. Jones
Saco-Lowell Shops

From the management point of view, design is the most important factor in lubrication problems. The advantages and disadvantages of individual bearing vs. central systems, oil vs. grease, and plain bearings vs. anti-friction bearings are discussed. Many new techniques are necessary due to use of new types of bearings and new materials. Various methods of providing lubrication instruction by the manufacturer are described and recommendations for applying lubricants in textile mills are given.

THE CRITICAL RAKE ANGLE METHOD OF EVALUATING CUTTING FLUIDS

by W. E. Lauterbach, Albright Co.
E. A. Ratzel, Midwest Res. Inst.

An experimental method of evaluating cutting fluids has been extensively investigated. The method consists of gradually changing the rake angle of a cutting tool in a two-dimensional cutting process and observing the change in chip formation and surface of the workpiece. The angle at which the chip changes from discontinuous to continuous is termed the "critical rake angle," and is taken as a characteristic of the cutting fluid. The method shows reproducible sensitivity to changes in cutting fluids and other cutting conditions. An evaluation of several fluid samples corresponds favorably with an empirical field rating of these fluids.

It is found that (1) the depth of cold work and (2) the magnitude and direction of the resultant tool force are approximately constant for the cutting fluids at their respective critical rake angles. This substantiates a hypothesis that at the critical rake angle, some important characteristics assume definite numerical values since they are a consequence of the mechanical behavior of the work material during the process of chip formation. Thus, a "figure of merit" (calculated from the critical rake angle for the cutting fluid) has a definite correlation with the field performance since the only variables present in the laboratory evaluation are the fluid and the rake angle.

THE DEVELOPMENT OF SIGNIFICANT BENCH TESTS FOR AIRCRAFT TURBINE LUBRICANTS

by E. A. Ryder
Pratt & Whitney Aircraft Co.

The rapid development of jet engines since the end of the war has brought on lubrication problems faster than it has been possible to solve them. The conventional bench tests for conventional lubricants have to be supplemented by additional tests for properties which were formerly not called into question such as gear load capacity, coking tendency, etc. The paper lists some of these properties and describes some of the tests which have been proposed.

THE EFFECT OF LUBRICANT VISCOSITY ON THE COOLING & LUBRICATION OF CYLINDRICAL ROLLER BEARINGS AT HIGH SPEEDS

by W. J. Anderson & E. F. Macks
NACA Lewis Flight Prop. Lab.

The effect of lubricant viscosity on the operating temperatures of a 75 mm bore cylindrical roller bearing is discussed, together with the effect of viscosity on the lubrication system heat load. The reasons underlying these effects are analyzed, and test data are untilized to show the validity of the analyses. A previously developed cooling correlation analysis, which generalized the test rig results, is extended to include fully the effects of oil viscosity. A cooling correlation curve may be developed for any specific bearing installation to enable the designer to predict the bearing operating temperature from a single curve regardless of oil inlet temperature, oil inlet viscosity, or oil inlet velocity vary over wide ranges.

THE LUBRICATION CHARACTERISTICS OF SYNTHETIC LUBRICANTS AT HIGH SLIDING VELOCITIES

by R. L. Johnson, M. A. Swikert & E. E. Bisson
NACA Lewis Flight Prop. Lab.

New types of lubricants are necessary to meet the stringent requirements of future aircraft turbine engines. Since many of the rubbing surfaces in these engines operate under conditions of boundary lubrication, the friction and surface-failure properties of the lubricant are of extreme importance. In consequence, the boundary lubrication characteristics of several classes of synthetic lubricants were studied over a wide range of sliding velocities at the NACA laboratories.

Most synthetics, including diesters, polyethers, a silicate ester and a phosphonate ester are more effective boundary lubricants at high sliding velocities than petroleum oils of comparable viscosity at 100 F. The breakdown of effective lubrication takes place at a much higher sliding velocity with these synthetic fluids than with the petroleum oils. A silicone-diester blend proved to be a much more effective boundary lubricant at high sliding velocities than either the silicone or the diester. A diester failed to lubricate non-reactive surfaces which indicates that the lubrication mechanism for diesters may involve chemical reaction with the lubricated surfaces.

THE LUBRICATION REQUIREMENTS OF GEARS AS SEEN BY A GEAR ENGINEER

by L. J. Collins
General Elec. Co.

From the standpoint of successful operation, a gear is dependent upon the proper choice of lubricant. There are a number of factors which should be considered, some of which are: (1) Accuracy of tooth spacing, (2) Surface finish, (3) Tooth modification, and (4) Sliding velocity. In this paper the author will discuss these factors and their effect on the type of lubricant required.

THE MECHANISM OF FRETTING

by I-Ming Feng & B. G. Rightmire
Mass. Inst. of Tech.

The purpose of this paper is to present a new mechanism of fretting based on the mechanism of wear suggested by Feng (I. M. Feng, J. Appl. Phys. 23, 1011, 1952). Concentrated mechanical wear is considered as the primary cause of fretting. The secondary causes of fretting are the accumulation of trapped wear product and oxidation of wear particles. Fretting corrosion can be stopped by eliminating its primary cause. Removal of secondary causes helps only in reducing the fretting damage. Experimental results obtained by the authors and also other investigators are given and cited here for supporting this new mechanism of fretting.

THE RELATIONSHIP OF LABORATORY TESTS TO LUBRICANT SUITABILITY IN THE TEXTILE MILL

by K. P. Powers
Gulf Oil Corp.

The physical and chemical laboratory test properties conventionally used in describing textile machine lubricants are briefly reviewed. It appears that viscosity is the most important single physical property relating to these lubricants. The lubrication requirements of the following types of textile machinery are examined: spindles, card comb boxes, tenter chains, drafting rolls, twister rings, and looms. It is concluded that conventional physical and chemical laboratory tests, with the exception of viscosity, are of little value in selecting lubricants for application in textile mills. There is no substitute for experience and background in this respect, and the oil industry should be relied on to make suitable recommendations regarding lubricants and their applications in the textile industry.

(Balance of Abstracts will appear in next issue.)

Lubrication in the News

ALEMITE LUBRICATOR: Lubrication of conveyor trolley wheels, long either neglected or done by hand with resultant conveyor stoppage, waste of manpower and lubricant, and risk of injury to workmen performing the job, has been made automatic, certain and safe by a new and unique lubricator just announced that delivers a pre-set, constant shot of either oil or lubricant to each trolley wheel on each side of the conveyor system into which it is installed, simply by the flick of a switch. When every wheel in the system has been serviced, the system may be switched off and is in constant readiness to go into operation again at whatever lubrication interval load and other conditions require. The new lubricator, sold as a "package unit," includes the lubricant reservoir, right and left hand lubricator assemblies with protective covers and anchor plates, and, as an accessory to the trolley wheel lubricator, the manufacturer's oil mist system can be installed to automatically lubricate chain linkage and knuckle joints of load pendent hooks. For further information write: Alemite Div., Stewart-Warner Corp., 1828 W. Diversey Blvd., Chicago 14, Ill.

DAG COLLOIDAL GRAPHITE AS A HIGH-TEMPERATURE LUBRICANT is a new, illustrated bulletin describing how DAG colloidal graphite has been used successfully to lubricate kiln cars at 450 F., oven conveyors up to 1200 F., and forging dies at over 2000 F., operating conditions where commonly used oils and greases are ineffective. Copies may be obtained by writing: Acheson Colloids Co., 1630 Washington Ave., Port Huron, Mich.

DRAWCOTE APPLICATING MACHINE, designed especially for the application of lubricants to sheets and blanks, has been announced that combines with the unique advantages of Drawcote, the company's dry lubricant, to reduce stock preparation costs and speed production in many metal forming operations. Material can be processed through this machine at speeds up to 55 feet per minute. Rotary brushes clean the stock with an alkaline cleaner; operation of brushes on both top and bottom of material during wash and rinse stages assure fast, positive cleaning. Steam-heated, fully enclosed solution tanks can handle blanks up to 48 inches in width; even, sure coating for maximum drawing compound economy is assured. Units are shipped completely assembled. Only minor pipe and electrical connections are necessary. Equipment is custom-built to individual requirements. Complete information may be had by writing: Gilron Products Co., 6007 Euclid Ave., Cleveland 3, Ohio.

GULF MOLDGLOSS A, an improvement in mold spray oil for use on high speed glass container forming machines, has been developed to keep the blank molds used in this operation properly coated and cleaner for longer periods of time, adding to efficiency and reducing shutdowns. Combining colloidal graphite, other additives, and the proper petroleum oil, these are formulated in the most effective percentages to maintain a uniform coating of carbon on the blanks, without excessive buildup of deposits, for long periods and over a wide range of operating temperatures. Can be used under most conditions as a mold spray oil, and in certain cases as swabbing compound, on automatic glass container forming machines; it can be used as a concentrate or additive for blending with straight mineral oil stocks when spray oils with lower concentrations of colloidal graphite can be used satisfactorily; it is also suitable for general use as a lubricant on glass forming machines where a low viscosity oil containing colloidal graphite is required. For further details write: Gulf Oil Corp., Gulf Bldg., Pittsburgh 30, Pa.

HILCO HYFLOW OIL RECLAIMERS are now available in higher capacities. These units, being used extensively for the purification and maintenance of transformer insulating oils, vacuum pump lubricating and sealing oils, lubricating oils used in diesel and gasoline engines, and many other types of industrial oils, contain all the necessary components to properly reclaim or purify by removing all types of contamination from the kind of oil they are intended to handle. Available in capacities up to 500 gallons per hour, filters only for combination with vaporizers, or the vaporizers separately, most units are made up to customer requirements, requiring floor space from 10 to 100 square feet. For complete details write: The Hilliard Corp., 102 W. 4th St., Elmira, N. Y., Bulletin R-247.

HYPERTAP, a blind-hole tapping lubricant extruded in solid stick form, similar to candles in shape, has been newly developed to assist in the tapping of threads in blind-holes (holes which do not entirely pierce through the metal or plastic parts). It eliminates tapping operations preliminary to bottoming by its automatic-hydraulic removal of chips from the hole during the thread-cutting operation, permits the use of finishing or bottoming taps at the very start of the thread-cutting operation, and facilitates the tapping of holes to within 1½ threads of the bottom without the necessity of backing out of the hole to remove accumulated chips. Sticks can be furnished in any specified diameter (current production, however, is confined to diameters ranging between 9/64" to 1"). Standard lengths are 3½" and 7½"; the standard package is 3 lbs. net. Further details and illustrations may be had by writing: Destiny Products Co., Executive Offices, 2970 W. Grand Blvd., Detroit 2, Mich.

JOHN CRANE TYPE 19 SEAL, a new all-purpose mechanical seal completely proven in design and construction, has been announced that provides life-time performance in small pumps, hot water circulators, and many other rotary shaft applications. Special beveled cones made of Teflon are utilized as the flexible member. This adapts the seal for services involving water, oil, corrosives or acids; temperatures from minus 100 to plus 450 F.; vacuums and pressures to 200 psi; and high shaft speeds. Being a packaged type unit, it provides quick and easy installation for production

(Continued on page 106)

Personals

C. E. SCHMITZ, former ASLE president, has been appointed Vice-President in Charge of Sales for the Crane Packing Co., Chicago, manufacturers of mechanical packings, mechanical seals, Teflon parts, and lapping machines.

Lincoln Engineering Co., St. Louis, manufacturers of lubricant application equipment for all industries, has announced the appointments of A. J. GRUENEWALD as Sales Manager, Industrial Division, and T. V. PICRAUX as Production Manager of both the Company's plants.

H. D. HUGHES has been appointed General Sales Manager and E. E. FOGLE, Sales Manager, of the Industrial Chemicals Div., Carbide & Carbon Chemicals Co., a Division of Union Carbide & Carbon Corp., New York.

The Hilliard Corp., Elmira, N. Y., manufacturers of HILCO lubricating, fuel, and industrial oil purification equipment has announced the appointment of T. A. LaBRECQUE as Vice-President.

C. R. KLUGE, ASLE National Office, has been advanced to Associate Editor of LUBRICATION ENGINEERING.

Aro Equipment Corp., Bryan, Ohio, has announced the appointment of J. F. NEFF as Division Manager for Aro products in Toledo and surrounding areas, with headquarters at 1010 Madison Ave., Toledo.

O. E. TEICHMANN of Armour Research Foundation of Illinois Institute of Technology has been named Conference Director for the 9th Annual Meeting of the National Conference on Industrial Hydraulics. F. W. EDWARDS, R. E. PECK, and V. L. STREETER will serve as committeemen, with J. G. DUBA as conference secretary.

At the E. F. Houghton & Co., Philadelphia, organization meeting following the annual stockholders meeting, J. F. MAISCH was elected Treasurer, A. E. CARPENTER was re-elected Chairman of the Board, and W. F. MacDONALD was re-named President.

J. P. HAMER, Standard Oil Development Co., Linden, N. J., coauthored a paper entitled "Lubricants—The Surface Savers" which was presented at the recent SAE Annual Meeting in Detroit.

W. C. BRYANT has joined Magie Bros. Petroleum Products, Chicago, as Research Director in charge of all product development on lubricating greases, process oils, cutting oils and core oils.

Book Reviews

ADDITIVES
by Petroleum Educational Institute, Publishers, 9020 Melrose Ave., Los Angeles 46, Calif., 1953, 80 pages, 110 illustrations, price $1.50.

The Petroleum Educational Institute has published a pocket-size booklet entitled ADDITIVES which describes new and late developments in the field of additives used in industrial and automotive oils and greases. It offers an elementary explanation of: (1) The problems which are solved or relieved by use of present day additives, (2) The action of present day additives which attacks the problem to be solved, (3) How the action of present day additives serves to attack the problem, (4) The several test engines used to evaluate the merits of present day additives, (5) Procedure of the "L" series and other tests used to evaluate additive type oils, and (6) The API Service Classification and Designations for automotive-type engine oils.

Current Literature

A THROW-AWAY FILTER MEDIUM
by Anon, Canadian Chemical Processing, Vol. 36, No. 13, Dec. 1952, pp. 50, 52.

A new low-cost filter medium, neoprene treated paper, has been evaluated as a complete or partial replacement for cotton cloth on plate and frame filters. It has been found that the physical and chemical properties of this material are adequate for many services and that its low cost results in substantial savings. The new type filter is now being tested. The paper is a new material being marketed by Canadian Industries, Ltd. It is a 100-lb. porous kraft containing 5 per cent neoprene synthetic rubber.

AERATION & FOAMING IN LUBRICATING OIL SYSTEMS
by R. Tourret & N. White, Journal of the Institute of Petroleum, Vol. 38, No. 346, Oct. 1952, p. 568A.

The authors give a survey of the existing state of knowledge regarding oil aeration and foaming, with particular reference to the aero-engine. The troubles that can be caused by oil aeration and foaming are summarized. The behaviour of air and gases in a liquid is treated theoretically, and the mechanism of foam formation is described. In a short section dealing with lubricant properties affecting foaming, attention is drawn to the influence of contamination with gasoline, water, or gasket sealing compounds on the foaming characteristics of an oil. Methods of overcoming aeration and foaming in aero-engines are discussed.

ARE MOTOR OIL ADDITIVES USEFUL?
by Anon, National Petroleum News, Vol. 45, No. 3, Jan. 21, 1953, pp. 74-76.

The marketing of so-called packaged crankcase oil additives has become a multi-million dollar business. Opinion as to the actual value or usefulness of these products varies all the way from "no good" to "best in the world." The lubrication chief of a nationally known oil company made a study of the so-called additives on the market today. Based on his own laboratory tests and lab test reports from other oil companies, he prepared an analytical report for distribution within his own company. Facts and fallacies, advantages and disadvantages are discussed. A number of brands of oil additives contain oil soluble lead soaps. The apparent purpose of these lead soaps is as an "oiliness" agent, since lead soaps do have some such properties under conditions of extreme pressures. However, oil soluble lead compounds are violent oxidation catalysts and will accordingly cause otherwise highly stable oils to oxidize and break down on exposure to high temperatures, with resultant formation of oxidation sludges and varnishes.

BRITAIN REPORTS NEW LUBE
by Anon, Oil & Gas Journal, Vol. 51, No. 35, Jan. 5, 1953, p. 141.

Shell has developed and received British Ministry of Supply approval for a jet-engine lubricant which is described as facilitating the immediate operation of new engines which could not otherwise have gone into service. The product, Aero Shell Grease 12, was developed after intensive research at Shell's laboratory at Thornton, Cheshire, and is said to be the only grease giving satisfactory performance in actuators and similar equipment. It is made with an inorganic gelling agent and synthetic oil. The manufacturers claim it has satisfactory lubricating properties over a temperature range, depending on con-

ditions, of between minus 70 C. and plus 200 C.

DISCOVERY SIGNALS BETTER LUBRICANTS

by Anon, Journal of Commerce, New York, Vol. 235, No. 17,817, Jan. 22, 1953, pp. 1, 15.

Scientists at the Naval Research Laboratory have found that certain lubricating compositions, which had large amounts of both a certain type of pro-oxidant (oxidizing agent) and a certain type of anti-oxidant, stood up well against deterioration by heat. The Office of Technical Services reported that the pro-oxidants are lithium soaps, and the anti-oxidants are certain types of organic compounds of silicones.

EFFECTS OF SOLID INCLUSIONS IN SLEEVE-BEARING OIL SUPPLY

by H. G. Rylander, Mechanical Engineering, Vol. 74, No. 12, Dec. 1952, pp. 963-966.

Sleeve bearings operated under normal conditions are always subjected to some foreign solid particles in the oil supply. Internal-combustion engines produce solids in the combustion process; other particles are produced by wear; and others enter as dirt, rust, and scale from the air or piping. A thorough understanding of the operating characteristics of sleeve bearings when subjected to certain particles in the oil leads to an improved design of bearings, shafts, oil, and oil filters. In order to improve the test accuracy, a large number of test points were recorded from which the conclusions were obtained, based upon average operating conditions.

FILTRATION

by S. A. Miller, Industrial & Engineering Chemistry, Vol. 45, No. 1, Jan. 1953, pp. 68-73.

A booming year for filtration, symbolized by the opening of two large, new plants by established manufacturers of clarifying filters and diatomite filter aids, respectively, is attested by the greatest number of publications ever reported. Contributions to theory have been in the realms of cake washing, filter-medium filtration, and indirectly, packed bed permeability. Equipment advances include new pilot filters, a pressure filter with retractable leaves and manifold, and vacuum filters of rubber- or plastic-coated construction. Performance data have been reported for coal dewatering, wood pulp thickening, water deoiling, and continuous precoat sirup clarification. Synthetic-fiber filter media are now available as clarifier cartridges. Acrilan has joined the family of synthetics and Teflon is produced in microporous sheets, and porous stainless steel has been given a smooth finish. A revised-edition monograph and an encyclopedia entry devoted to filtration have appeared, along with reviews of theory, filter selection, the variables affecting filtration rate, and the causes of filter fabric failure. 221 references are given.

HOW MUCH DIRT CAN HIDE IN AN AUTOMOBILE CRANKCASE?

by H. Ridder, National Petroleum News, Vol. 45, No. 6, Feb. 11, 1953, pp. 30-34.

This article shows visually, and with laboratory data, just how dirty motor oil can get, and how quickly it can become contaminated to the point that it no longer does a good job of lubricating the engine, but rather contributes to engine wear.

KNOW YOUR OIL WORDS

by Anon, Petroleum Processing, Vol. 8, No. 1, Jan. 1953, pp. 70-71.

An up-to-date list of glossaries of petroleum terms has been compiled by the Petroleum Section of the Special Libraries Assn. The list is given.

LUBRICANT FOR ROCKET MOTORS

by Anon, Chemical Engineering, Vol. 60, No. 1, Jan. 1953, p. 108.

Modern rocket motors in aircraft and missiles call for lubricants that can withstand powerful oxidizing agents. A lubri-

(Continued on page 108)

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ALLEN, C. M., Battelle Mem. Inst., Columbus, Ohio.

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BRYCE, H. G., Minn. Mining & Mfg. Co., St. Paul, Minn.

CARTER, R. J., Gemmer Mfg. Co., Detroit, Mich.

CASSIN, H. E., Sun Oil Co., Kenmore, N. Y.

CAWLEY, H., Alemite Co. of N. Texas, Dallas, Tex.

COOKE, G. R., Stewart-Warner Corp., Chicago, Ill.

DEWITT, R. N., Aldridge Ind. Oils, Inc., Cleveland, Ohio.

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FATOUT, R. C., Alvord Oil Co., Indianapolis, Ind.

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HADLEY, W. C., Paget, Bermuda.

HALPIN, M. J., U. S. Army, Syracuse, N. Y.

HARROD, C. C., Gulf Refg. Co., Cleveland, Ohio.

HERMAN, E. S., Lockheed Aircraft, Burbank, Calif.

HOVEL, E. L., Humble Oil & Refg. Co., Abilene, Tex.

HOWARD, N. A., Jr., Manufacturer's Rep., Los Angeles, Calif.

HUGHEY, J. D., The Paquin Co., Cincinnati, Ohio.

JOHNS, C. M., Cleveland Worm & Gear Co., Cleveland, Ohio.

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MANLEY, L. W., Socony-Vacuum Oil Co., Inc., Woodbury, N. J.

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STUART, C. B., Shell Oil Co., Youngstown, Ohio.

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WEGER, J. J., Kaiser Mfg. Corp., Dowagiac, Mich.

YOUNG, W. H., Jr., Tide Water Assoc. Oil Co., Hartford, Conn.

Section News

BOSTON: Jan. meeting—A Mr. Spellman, E. I. Dupont Co., discussed the solving of some of the unusual problems he had encountered as a Machine Tool Consultant. H. E. Mahncke, Westinghouse Research Laboratories & ASLE Eastern Regional Vice-President, presented the section with their official ASLE Charter. (Submitted by A. S. McNeilly, Sec'y.)

BUFFALO: Jan. meeting—J. P. Critchlow, Gulf Oil Corp., presented a paper entitled Extreme Pressure Lubricants & Their Application, and added his predictions for the future.

Feb. meeting—Turbine Lubrication & Turbine Cleaning Procedures was presented by A. S. Morrow, Shell Oil Co.

March meeting — A joint meeting with the National Association of Corrosion Engineers with E. S. Francis, Gulf Research & Development Co., presenting a paper entitled Preservative Lubricants & The Part They Play In The Care & Operation Of Motorized Equipment.

April meeting—A two hour panel entitled Lubrication Maintenance to be presented at the Technical Societies Council of the Niagara Frontier meeting (April 22) at the Hotel Statler, with K. E. McHenry, Bethlehem Steel Co., presiding. (Submitted by W. M. Pitcher.)

CHICAGO: Jan. meeting—R. L. Taylor, U. S. Steel Corp., presented a paper entitled Function Of A Lubrication Department In A Steel Mill (originally presented at the recent American Iron & Steel Institute Convention in Cleveland), followed by a discussion.

Feb. meeting—Ladies Night, with Miss Francis Ireland, Bowman Dairy weekly television, show, entertaining with magical fantasies, followed by a technicolor travelog and Name Bands sound movies with W. P. Youngclaus, Jr., ASLE Administrative Secretary, acting as Master of Ceremonies. (Submitted by A. B. Two, Sec'y-Treasurer.

CONNECTICUT: Jan. meeting—H. L. Worthington, Remington Arms, Inc., presented a paper entitled Plant Lubrication, first explaining the duties of a Lubrication Engineer which included developing and maintaining all equipment in good lubricating order, issuing instructions as to the kind and frequency of lubricant to use, training of fellow employees, cooperation, the checking of and maintaining economy, and to personally follow up and investigate all failures. He particularly stressed the advantages of central and automatic lubricating systems. (Submitted by R. F. Casella.)

DAYTON: Jan. meeting—E. W. Fisher, The Garlock Packing Co., presented a paper entitled Lip Type Seals For Rotating Shafts, pointing out that to specify a seal, factors of speed, temperature, shaft size, and fluid must be considered. Discussing seal materials, he stated that leather, which was once very popular, is now displaced largely by such materials as Hycar and other oil resistant rubbers and such plastics as Teflon. In discussing seal designs, Fisher stated that the spring-backed garter type may not be suitable in dirty places due to the fact that solid dirt may accumulate to the point that the spring action is lost. The lip is always installed to the outside so that internal pressures will tend to be released.

Feb. meeting—S. D. Craine, W. A. Jones Foundry & Machine Co., addressed the section on the subject What The Lubrication Engineer Can Do To Reduce Premature Gear Failure, discussing the causes of gear failures under the headings of improper selection, inadequate supporting structure, and improper operation. Excerpts include: ". . . practically all gear failures are premature since gear manufacturers design their products to outlast the rest of the machine. The insipient failures can be detected and prevented by the institution of a gear inspection program under the experienced eye of the lubrication engineer. . Mechanical conditions are by far the greatest cause of gear trouble while only few of the types of failures are attributable to poor lubrication . . ." (Submitted by A. H. Turner, Vice-Chairman.)

FORT WAYNE: Feb. meeting—H. W. McCulloch, Wood River, Illinois Div. of Shell Oil Co., presented a paper entitled Inhibited Transformer Oils. (Submitted by R. L. Gruenert, Chairman.)

MILWAUKEE: Jan. meeting—R. S. Norris, Shell Oil Co., presented a paper entitled Detergent Type Motor Oils.

Feb. meeting—R. Childs, Waukesha Motor Co., presented a paper entitled Motor Fuel Evaluation. (Submitted by R. W. Schroeder, Sec'y.)

NEW YORK: Jan. meeting—E. K. Bloss, Boston & Maine Railroad, discussed diesel lubrication as applied to railroads, outlining the back history of locomotive development through the early steam engine to the present diesel. World War II increased the use of diesel locomotives and the originally used oils showed corrosion and deposits which became serious maintenance problems; materials of bearing construction were limited due to critical shortages and the oils had to be reformulated to give maximum protection. It was felt that U. S. Army Specification 2-104B oils solved most of the problems. However, the years following the war saw changes along the lines of increased power output with smaller diesel engines and the use of higher sulfur fuels which made it necessary to increase the additive contents of the oils. Bloss does not consider diesel locomotive lubrication problems solved by the use of the higher additive oils such as Supplemental I and Series II levels. He recommends that the oil companies get together with the equipment manufacturers and attempt to solve their problems before new locomotives are delivered. The paper was followed by an enthusiastic question and answer period.

Feb. meeting—Ladies Night, with Miss Beatrice A. Hicks, Newark Boiler Regulator Co., speaking on the subject Women In Engineering. She outlined the many new fields which require engineers and indicated the great need for additional engineering students. She feels that more girls should be encouraged to study engineering with the idea of later employment in labora-

(Continued on page 104)

Coming Events

APRIL

13-15 American Society of Lubrication Engineers (8th Annual Meeting & Exhibit), Hotel Statler, Boston, Mass.

15-17 National Petroleum Assoc. (Semi-annual Meeting), Hotel Cleveland, Cleveland, Ohio.

24-25 Interstate Oil Compact Comm. (Spring Meeting), Roosevelt Hotel, New Orleans, La.

26-29 American Inst. of Chemical Engineers (Joint meeting with Chemical Inst. of Canada), Royal York Hotel, Toronto, Can.

27-28 Independent Petroleum Assn. of America (Mid-Year Meeting), Jefferson Hotel, St. Louis, Mo.

29-May 1 Natural Gasoline Assn. of America (Annual Convention), Rice Hotel, Houston, Tex.

MAY

4-6 Liquefied Petroleum Gasoline Assn. (Annual Convention & Trade Show), Conrad Hilton Hotel, Chicago, Ill.

11-13 Southern Gasoline Assn., Jung Hotel, New Orleans, La.

14-23 International Petroleum Exposition, Tulsa, Okla.

17-19 Empire State Petroleum Assn., The Roosevelt Hotel, New York, N. Y.

24-27 American Gas Assn. (Production & Chemical Conference), New Yorker Hotel, New York, N. Y.

28-29 Western Petroleum Refiners Assn. (Regional Meeting), Broadview Hotel, Wichita, Kan.

JUNE

4-5 Kentucky Oil & Gas Assn. (Annual Meeting), Lafayette Hotel, Lexington, Ky.

7-12 Socy. of Automotive Engineers (Summer Meeting), The Ambassador & Ritz-Carlton Hotels, Atlantic City, N. J.

Patent Abstracts

Prepared by ANN BURCHICK from OFFICIAL GAZETTE, Vol. 665, No. 5; Vol. 666, Nos. 1, 2, 3, 4; Vol. 667, Nos. 1, 2, 3. Printed copies of patents are available from the Patent Office at twenty-five cents each. Address the Commissioner of Patents, Washington, D. C., for copies and for general information concerning patents.

OIL COMPOSITION, Patent #2,623,852.
by W. H. Peterson, assignor to Shell Development Co.

An oleaginous composition having high resistance to disintegration by water comprising an oleaginous liquid thickened to a gel grease-like consistency by addition thereto of from about 1% to about 20% by weight of said composition of an initially hydrophilic solid inorganic gel and from about 10% to about 100% by weight of said inorganic gel of an at least partially oleophilic poly amino oxy compound containing at least 3 amino nitrogen atoms and oxy groups together spaced apart in the molecule by not more than 10 carbon atoms.

GREASE COMPOSITIONS, Patent #2,623,853
by Fred H. Stross, assignor to Shell Development Co.

A grease composition comprising an organic lubricating liquid having colloidally dispersed therein a grease-forming amount of a clay having a base exchange capacity of at least 25, the colloidal particles of said clay having absorbed on the surfaces thereof from about 25% to about 100%, based on the weight of the clay, of a cationic hydrophobic surface-active agent, the nitrogen atoms of the said agent being substantially only in the trivalent state.

LUBRICATING GREASE COMPOSITIONS, Patent #2,623,854
by A. J. Morway, & P. V. Smith, Jr., assignors to Standard Oil Develpment Co.

A lubricating grease composition consisting essentially of a lubricating oil thickened to a grease consistency with from 5 to 20% by weight of a mixture of from 1 to 3 parts of an alkali metal soap of a high molecular weight fatty acid and from 1 to 2 parts of an alkali metal salt of a low molecular weight oxy acid.

LUBRICATING COMPOSITIONS, Patent #2,623,855
by P. J. Garner, assignor to Shell Development Co.

A mineral lubricating oil composition having incorporated therein from 0.01% to 5% by weight of an alkyl phenol having the formula ROH wherein R is an alkaryl hydrocarbon radical containing an alkyl group having from 8 to 18 carbon atoms and as the only sulfur containing compound wherein sulfur is present as a sulfide about 0.01% to 5% by weight of a sulfurized cracked wax olefin, said cracked wax olefin having an average molecular weight of about 185, containing from 10 to 18 carbon atoms per molecule, containing substantially only terminal double bonds and having an average of about 0.9 double bond per molecule.

LUBRICATING COMPOSITION, Patent #2,624,707
by G. G. Pritzker & D. E. Adelson, assignors to Shell Development Co.

An oleaginous base having incorporated therein an amount sufficient to stabilize against deterioration and impart extreme pressure properties to said base, a metal-free reaction product obtained by reacting at reflux temperature a phosphorus sulfide with a heterocyclic ring compound selected from the group consisting of thiophene, benzothiazole, and alpha, alpha-dipyridyl compounds in the mole ratio of 1:5 to 2:1, respectively.

WATER RESISTANT GREASE, Patent #2,625,508
by F. H. Stross, assignor to Shell Development Co.

A non-aqueous lubricating composition comprising a major amount of a lubricating oil as the essential liquid phase having dispersed there-through an anhydrous preferentially water wettable inorganic gel in a colloidal state capable of forming a grease with said lubricant and a minor amount based on the inorganic gel of a hydrophobic metallic soap of a soap forming organic acid, the amount of said soap being at least sufficient to provide a mono-molecular layer on the surfaces of the gel.

CUTTING FLUID AND COOLANT, Patent #2,625,509
by Ernst Laug, assignor to Socony-Vacuum Oil Co., Inc.

An aqueous emulsion-form coolant and lubricant composition of matter produced by compounding together

	Weight Percent
Potassium soaps of castor oil fatty acids	17 to 20
Triethanolamine soaps of castor oil fatty acids	2 to 5
Triethanolamine phosphate	8 to 13
Water soluble polyalkylene glycols	3 to 5
Rust inhibitive salts of sodium	2.25 to 4
Phenol germicide	1 to 1.5
Water	To balance
	100.0

LUBRICATING GREASE COMPOSITION, Patent #2,625,510
by R. J. Moore, assignor to Shell Development Co.

A lubricating grease comprising a major amount of a mineral oil having a viscosity index greater than 40, a minor amount of a soap to thicken the oil, and from 1% to about 20% by weight of an oxidized petroleum aromatic extract fraction obtained by solvent treatment of a petroleum distillate having a viscosity of 60 SUS at 210 F., said aromatic extract fraction having an aniline point between 25 and 75 C., said oxidized solvent fraction having been formed by exposure of the fraction and the grease forming components to air during grease forming operations at a temperature between about 175 F. and about 410 F.

ANTICORROSION AGENTS AND COMPOSITIONS COMPRISING THE SAME, Patent #2,625,511
by A. G. Rocchini, assignor to Gulf Research & Development Co.

An improved hydrocarbon oil composition comprising a major amount of a hydrocarbon oil and a minor amount of a nitrogen-containing compound selected from the group consisting of the amides and imides of substituted succinic acids having a substituent in the aliphatic chain, selected from the group consisting of the alkylthio and arylthio radicals, and an organic amine having only one amino group containing an N-hydrogen atom, the amount of said nitrogen=containing compound being sufficient to impart corrosion-inhibiting properties to said composition.

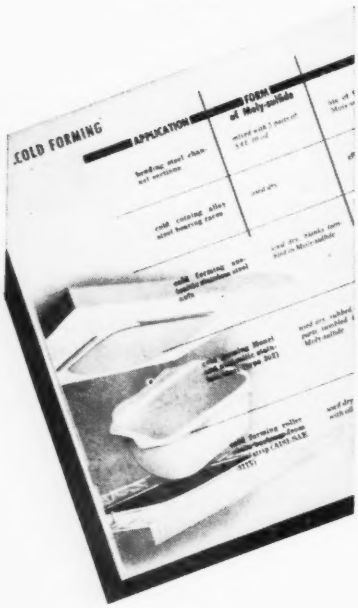
NONCORROSIVE SOLUBLE OIL CONTAINING ACTIVE SULFUR, Patent #2,626,240
by A. J. Deutser & F. T. Crookshank, assignors to The Texas Co.

A soluble oil comprising as the major constituent sulfurized mineral lubricating oil containing loosely combined active sulfur, an emulsifying agent capable of promoting the formation of

(Continued on page 110)

Moly-sulfide
A LITTLE DOES A LOT

shows up best where the frictional conditions are difficult



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(Grant, Continued from page 74)

tently poor life. With organic oil-metallic soap type greases a similar condition exists, but the gain in life with a loose bearing is small because the grease itself will not last long at 150 C.

DATA ON SILICONE OIL-LITHIUM SOAP TYPE GREASES: As with all materials, these silicone greases have certain limitations and satisfactory performance cannot be expected from them when operated beyond those limits. It appears that the results reported here were caused by the unintentional overloading of certain of the test bearings through mechanical design unsatisfactory for the thermal conditions.

As a lubricant for ball bearings, the recommended practice for the silicone oil-lithium soap type grease used in the tests reported here is as follows: OPERATING TEMPERATURES: —40 to +350 F. Higher temperatures can be used with increased frequency of relubrication. SPEED FACTOR: (Bore in mm) X (rpm) = 150,000 to 200,000. In some applications this has been exceeded with no difficulty. LOAD: Below 1/3 of catalog rating, life will be greater than with conventional high temperature organic greases. Above that, less life is to be expected[2,3,4].

Within these limits, and that includes most ball bearing applications, silicone oil-lithium soap type greases can do certain jobs that other grease cannot approach. Notable among them is the ability of one grease to operate at both high and low temperatures. At more normal temperatures such silicone greases will give satisfactory performance for very long periods of time without relubrication[2, 3, 5, 6]. This is proved by the fact that many thousands of bearings lubricated with silicone oil-lithium soap type greases have been in operation for years where other types of grease gave unsatisfactory service.

As indicated by the data given in this paper, unintentional overloading may be avoided by a more careful consideration of all the factors involved.

RECOMMENDATIONS: ABEC standard fits for this size bearing, in thousandths of an inch, are: theoretical, 0.1 mil loose to 0.5 mil tight; and expected, 0.0 mil loose to 0.4 mil tight. Thus, the critical range indicated in these tests (0.1 mil tight to 0.2 mil tight) suggests the use of shaft fits that are looser than those recommended in ABEC standards. Loose fits can be used if locking devices are incorporated in the design, but such practice is contrary to the recommendations of bearing manufacturers. A more acceptable way to increase the life of bearings lubricated with silicone soap-type greases therefore, would seem to be the use of bearings with maximum radial clearance. This can be done readily enough but the bearings will be noisier than normal at starting temperatures. They should quiet down however at operating temperature. A slight spring load on the shaft can be employed to reduce this noise. A more serious disadvantage might be the reduction of accuracy in precision equipment.

In conclusion, some recommendations are indicated. Wherever operating conditions are such that silicone grease is required, these same conditions produce thermal gradients that make mechanical fits too critical to be ignored. In view of

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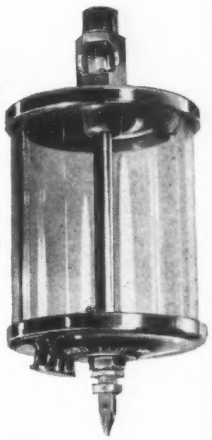

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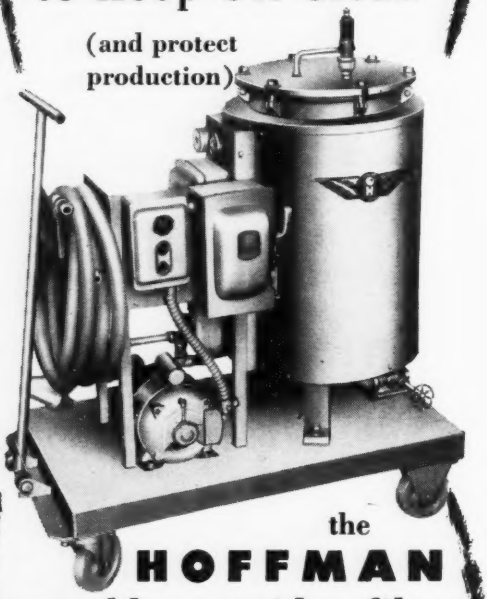

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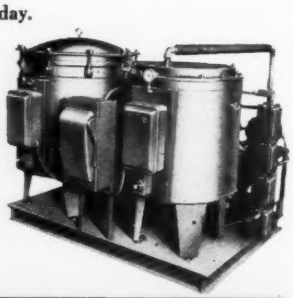

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this fact, it is suggested that designers observe the following recommendations: (1) Recognize the limitations of the grease, (2) Keep the temperature of the inner race down to or below that of the outer race, (3) Where bearing temperatures exceed 110 to 125 C., use specially heat treated or special alloy bearings which are suitable for the temperatures involved, (4) Use as loose a fit on the shaft as practical, (5) Use bearings having sufficiently large radial clearance, (6) Avoid large thrust loads due to thermal expansion of the shaft, (7) Be sure that bearings and shaft are carefully aligned.

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(Craine, Continued from page 72)

fore, sound policy to have an ample safety factor in the gear train. Completely balanced arrangement, precisely cut gears, dynamically balanced elements, bearings used that will last as long as the complete unit under every load imposed, and housings made heavy enough to prevent distortion under load with sturdy footings to hold the unit permanently in the proper position, etc. To write all these elements into a specification is just as impractical as it would be to expand on them in this paper.

The Lubrication Engineer can, however, serve his company well by observing the various units in operation in order to detect design weaknesses. Inspection shortly after a unit is installed and at periodic intervals afterward will catch design weaknesses far enough ahead of complete failure to secure an adequately designed replacement and still recover the original unit for some lighter application.

IMPROPER LOADING: In the four previous classifications of causes of premature gear failures we have accounted for the major portion of the loss. With all the aforementioned factors in order there are still many premature gear failures due to excessive loading which only an inspection program will bring to light.

The inspection program should include all large gear trains and also the smaller units if their failure could disrupt production. On these units an inspection should be made after the first month, the third month, and sixth month of full load operation. On all other units a complete check of the unit should be made if there is excessive heat, noise or frequent operation of motor cutouts. After the above initial inspections every important gear drive should be inspected once a year. On the first indication of trouble all external causes should be investigated and cleared. If there remains any evidence of excessive loading then a complete analysis of the operating conditions should be made. The information necessary to make a complete diagnosis of the cause of excessive gear loading is shown on Chart I. This information placed in the hands of

any competent gear design engineer will enable him to immediately spot the basic fault and make recommendations to correct it. Should the inspection indicate lubrication failure the same information may be required by the lubricant supplier.

CONCLUSION: For convenience in interpreting initial indications of gear failures, Chart II has been prepared summarizing information presented in this paper.

Early detection of gear difficulties is of paramount importance. The greatest savings in a program to reduce premature gear failures are, obviously, the savings in lost production. The savings in the cost of equipment and coincidental maintenance will pay many times the cost of an inspection program and the time in collecting data pertinent to proper gear operation.

(Bloodgood, Continued from page 84)

Board of Health or other similar agency. Some statisticians think they can prove that once a week is often enough. It is not feasible to specify an over-all sampling program because of the great variety of variables encountered from one situation to another. It is better to consider each case on its own merits. Insofar as sampling for oil is concerned, it should be borne in mind that the presence of floating oil on the effluent from a treatment system is an indication that the process is not functioning properly. Floating oil is difficult to estimate quantitatively, however, if the amount present is sufficient to cause only iridescence no great problem is being created.

Prof. Bloodgood in that part of his paper on "Legal Controls on Oil Waste Discharge" illustrates not only the broad coverage of anti-pollution laws but the overlapping of different level regulatory bodies. His opinion that firm knowledge of the effects of the contaminant should be known before a concentration figure is written into the law is certainly sound. I assume that he is referring to the general public's attitude on anti-pollution measures when he points out that it is unreasonable to expect legal agencies to set up narrow and specific regulations applicable to everyone. He implies that industries might demand narrow and specific regulations. This is probably based on a misunderstanding of industry's desire to know what kind of treatment facilities to design so as to provide what degree of treatment. It is perhaps naive to point out that treatment facilities cost money to install and to operate. These are expenses that add to the cost of a product and may affect a producer's position in the competitive field. There is no serious objection to such expenditures when they serve a good purpose established by sound reasoning and pertinent facts.

AUTHOR'S CLOSURE: It was only a few years ago that it was generally believed that organic oils could not be readily broken down and used as bacterial food. Today it is quite well known that under certain conditions bacteria readily use oils for food. It is possible that mineral oils may, under certain environmental conditions, be broken down by bacteria. It would seem to be a little dangerous to accept the statement of the Russians on this matter in view of their inclination to exaggerate.

The statements made regarding the numbers of samples that need to be taken, in order to keep a watchful eye on the discharges from plants using large quantities of oil was based on the assumption that the larger the industry the greater the need for adequate control. The assumption that the greater the number of samples the better the knowledge of the situation may not hold true when a statistical analysis of sampling is carried out.

It was only a few years ago that some industries with several plants in the same state demanded that the pollution abatement control authorities give a fixed figure for the maximum concentration of the polluting material that could be discharged in the effluent from all of the plants. Some of the more progressive agencies think that such rulings would not permit the economical abatement of pollution. It was the intention of the writer to bring out that reasonableness in pollution abatement is attained by careful consideration of each individual situation.

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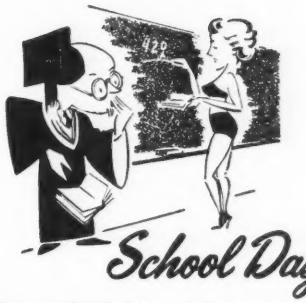

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(Lube Lines, Continued from page 69)

the interests of better management at the National Office. For instance, addressing and mailing equipment have been acquired to handle all requirements more efficiently. LUBRICATION ENGINEERING, the journal of the Society, has had its face completely lifted in the last nine months. The type face used and the cover were changed first. The Editorial Committee did a truly remarkable job by making more papers available and increasing coverage. This resulted in LUBRICATION ENGINEERING carrying 75% more editorial matter and articles than ever before. Additional improvements were made to improve reference and readability, layout and composition.

The 8th Annual Meeting of the Society at the Hotel Statler in Boston, April 13-14-15, will be truly something to remember. The Program Committee has arranged one of the finest series of papers ever presented; the Boston Annual Meeting Committee has done an excellent job in lining up additional activities for members, guests, and the ladies.

With continued cooperation of the membership, the American Society of Lubrication Engineers will make even greater strides, and 1953 should prove a banner year in ASLE history. W.P.Y.

(Bisson, Continued from page 77)

conditions, it was considered desirable to check the performance (from the standpoint of friction and prevention of welding) of MoS_2 included as a minor constituent of porous bearing materials made by powder metallurgy techniques. Such bearing materials might be capable of operating successfully even under extreme boundary lubrication conditions (possibly even completely dry). For these experiments, the materials were: copper (5 percent), silver (variable percent), and MoS_2 (variable percent). The friction and wear of such materials are shown in Fig. 5. Since these experiments were conducted dry, it is obvious that such materials show some promise for success in maintenance of low friction. At the same time, welding was completely prevented for all materials with MoS_2 concentrations greater than 5 percent. The studies indicated that these materials formed an effective lubricating film on the surfaces by a transfer of solid lubricant (MoS_2) from within the structure of the material.

Over-all analysis of the results obtained with surface films shows that naturally formed films may be very beneficial. It is suggested that preformation of such films might be quite effective in initially providing low friction and protection from welding. For example, preformation of an oxide film, Fe_3O_4, should help to prevent the initial seizure and welding of the surfaces of steel-on-steel. Also, since surface films are beneficial, they should help appreciably under those conditions where a very poor lubricant is used. Specifically, with silicones which are poor lubricants for

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steel-on-steel, preformation of the film formed by decomposition of the silicone might result in enough protection to the surfaces to allow the use of silicones as lubricants. Some experimental evidence with the silicones has been obtained which does, indeed, indicate this might be true. Ref. 11 states that the naturally-formed film increases the load carrying capacity of a journal bearing lubricated with a silicone. This result agrees with that of Ref. 7 which shows that the combination of a fluid film and a preformed surface decomposition film had good friction and anti-weld properties.

CONCLUDING REMARKS: The use of solid surface films may appreciably affect the friction and surface failure characteristics of steel on steel at high sliding velocities; some films show very beneficial effects and other films show harmful effects. Friction theory, which shows that a reduction in shear strength at the surface should correspondingly reduce both friction and tendency to surface failure, appears to be confirmed quite adequately. Preformation of "naturally-forming" beneficial films should be effective in preventing initial damage. Of the various solid surface films (which do not form naturally), one which shows considerable promise at high sliding velocities and extreme pressures is MoS_2. It is possible this material may also be effective under high temperature conditions in view of the fact that the results show the required film thickness is extremely small. It is also possible that MoS_2 may be effective as a dry lubricant when contained within the structure of a bearing made from powdered materials. The experimental results showed that surface welding could be prevented and dry friction coefficient could be maintained at a relatively low value.

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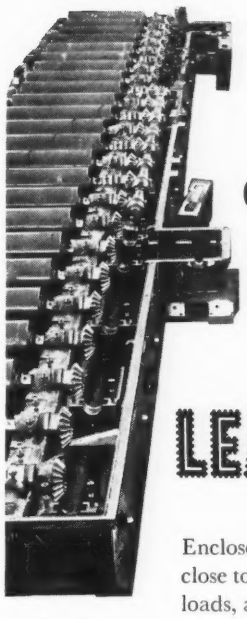

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(Cobb, Continued from page 80)
man, true rolling does not occur between balls and races in loaded bearings. True rolling occurs only in certain areas of the pressure ellipse. These areas of true rolling are shown in the unsectioned areas of the exaggerated pressure ellipse of Fig. 5.

When thrust is applied to the bearing the balls roll up toward one side of the race making the bearing operate as an angular contact bearing, and this imposes a spin on the balls which also tends to make the contact area pivot. The Hertz compressive stress may run as high as 350,000 to 550,000 psi and the surfaces must be lubricated by some medium having sufficient strength to keep asperities on balls and races separated. According to pure research conducted by Professor F. B. Bowden, Cambridge University (Bowden's basic studies are found in The Fundamental Aspects of Lubrication, published by The New York Academy of Sciences, Vol. 53, June 27, 1951), it is stated that if some medium which possibly could be classified as a lubricant is not present between the virgin metals, the material from balls, races, and separator will rapidly transfer to mating member making a rough bearing which will spall very rapidly or become too noisy. The mechanics of lubrication in this area are not well known; however, we do know that viscosity and film strength play an important part in keeping balls and races and balls and separators separated from metallic or intimate contact.

Ball bearing separators are made of many materials and designs. The contact areas between balls and separator constitute, in effect, a poorly designed plain bearing and all the difficulties experienced in non-pressurized plain bearings, plus a few extra, are encountered. At best, these pressure areas operate under partial lubrication which makes it imperative that separator material, where any speed is involved, be a material having an oxidized monolayer of base material which will adsorb lubricant. Here again reference is made to Professor F. P. Bowden's basic studies.

Under radial loading only, approximately half of the balls carry the load and are kept in contact with the races at any given instant. The remaining balls are loose in the bearing due to deflection of bearing components and this momentary relief allows lubricant to collect between balls and separator before balls re-enter the loaded phase. In bearings operating under pure thrust loading, all the balls are constantly loaded with continual pressure between the balls and races which keeps the separator in intimate contact with the balls making lubrication with grease difficult.

While means of running bearings at ultra high speeds in the laboratory are available, the test rigs are not entirely satisfactory. The chief difficulty, at present, is that each high speed test unit has certain adverse characteristics which influence test bearings more than bearing lubrication or design. However, every effort is being expanded to overcome these test conditions so that load ratings may be available for general usage, taking into account not only load and temperature but also ultra high speed and lubrication methods for bearings made to operate in such applications.

CORRECTION, December, 1952, LE: For both immediate interest and reference, the following illustrations from the paper Material Specifications For Oil-Film Bearings, by E. B. Etchells, Chevrolet Motor Div., GMC, are herewith reproduced in greater proportion. The content of each figure and table is indicated in the title but reference should be made to the original paper for further details.

	COPPER	ZINC	TIN	LEAD	ORDER OF SCORE RESISTANCE	ORDER OF INHERENT HARDNESS OR STRENGTH	SUGGESTED APPLICATIONS *
BRASS—BRONZE	85-90 (T) 86	Fe-2 Fe-2	Al-4-10 Al-4	— —	8	1	Very poor anti-score quality. Used in minor locations
	60-90 (T) 90	10-40 9	— —	0-2 ½	7	2	Same as above. Used with hypoid gear oils
	85-90 (T) 88	½-3 2	7-10 10	0-5 —	6	3	For heavily loaded piston pins and similar motions where surface speed is very low
	80-90 (T) 88 (T) 80	0-5 4 —	3-10 4 10	3-10 4 10	5	4	Average bushing materials for low speed, small diameter shafts
	70-75 (T) 72	* —	4-10 4	20-25 20	4	5	For moderate speed bushings and where lubrication is not well maintained
Aluminum alloys					3	6	For heavily loaded moderate speed bearings
Copper-leads					2	7	For heavily loaded high speed bearings
White metal alloys (Cadmium and Babbitts)					1	8	Low to moderately loaded, low to high speed bearings where dirt and deflections are present

Table I—Score resistance and strength of common bearing metals.

* Load PSI Speed ft./sec.
Low 1000 and under up to 5-10
Moderate up to 2000 up to 15-20
High over 3000 over 30
(T) Typical analysis

	ORDER OF FATIGUE STRENGTH	APPROXIMATE MAXIMUM LOAD, PSI	ORDER OF DEFORMABILITY
Bronzes	1	10,000	7
Copper-lead with tin or silver	2	3000-4000	6
Thin babbitt overlays (.003" or less)	3	2000-4000	5
Aluminum alloys	4	2000-3000	4
Copper-lead	5	1500-2500	3
Cadmium alloys	6	1200-1500	2
Lead and tin base babbitts	7	800-1500	1

Table II—Fatigue strength and deformability of bearing metals.

NO.	MATERIALS	RATING
1	Thick babbitt (0.032 in. thick)	124
2	Durex 100A	100
3	Copper (oxygen-free)	0.5
4	Gridded copper (48 pitch)	32
5	Silver (oxygen-free)	0.7
6	Copper + 0.0008 in. Pb-Sn alloy	50
7	Copper-lead (60 Cu, 40 Pb)	7.5
8	Copper-lead (65 Cu, 35 Pb)	5.5
9	Copper-lead (70 Cu, 30 Pb)	5.0
10	Copper-lead-tin (75 Cu, 24.5 Pb, 0.25 Sn)	4.0
11	Copper-lead-tin + 0.001 in. Pb-Sn alloy	69
12	Aluminum (95 Al, 4 Si, 1 Cd)	10
13	Aluminum + 0.0008 in. Pb-Sn alloy	68

Table III—Results of embedability tests on various materials.

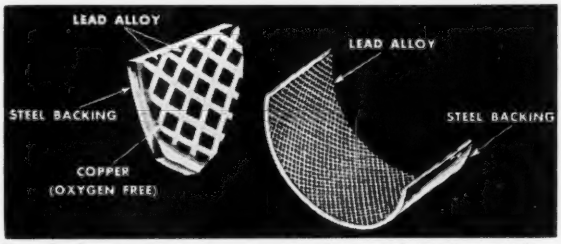


Fig. 2 Construction of a steel-backed grid bearing with a copper grid filled with a soft lead alloy.

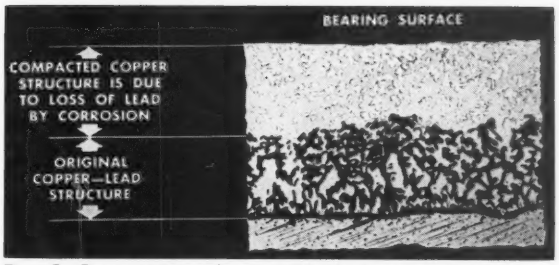


Fig. 3 Cross-section of a steel-backed copper-lead bearing illustrating the penetration of corrosion (loss of lead) into the upper or bearing surface.

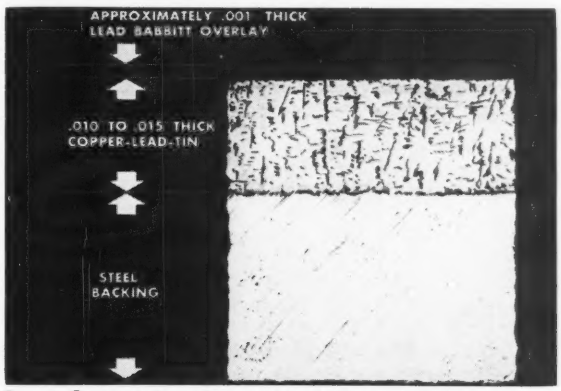


Fig. 4 Cross-section of a steel-backed tri-metal bearing on a copper-lead-tin sub-base.

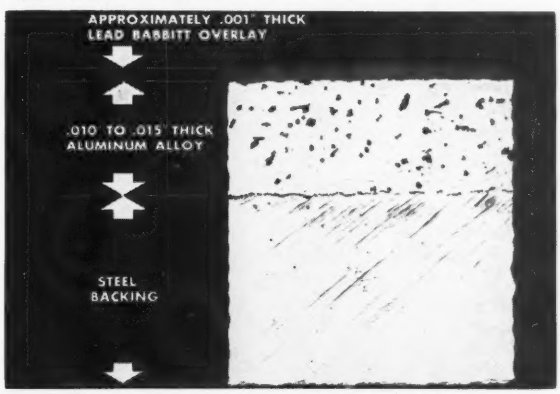


Fig. 5 Cross-section of a steel-backed tri-metal bearing on an aluminum-alloy sub-base.

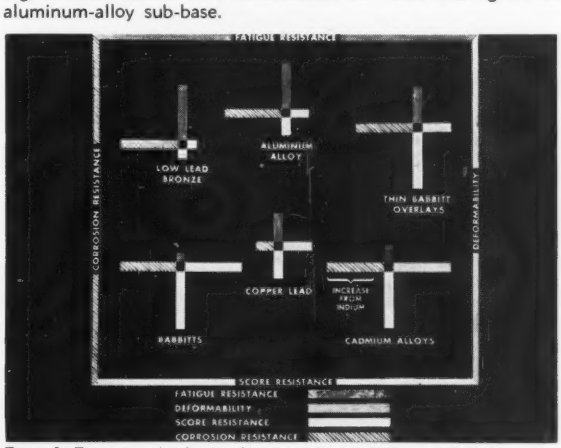


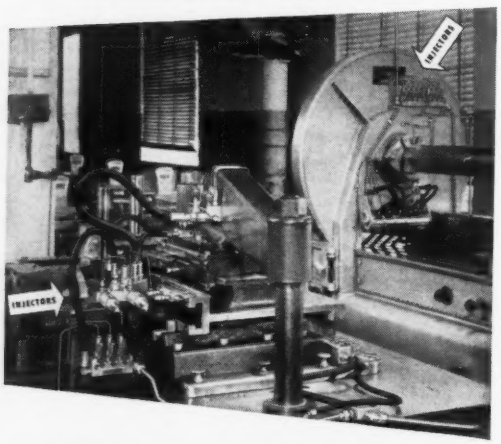
Fig. 6 Functional chart showing how different bearing materials compare in regard to the four important performance properties: fatigue resistance, deformability, score resistance and corrosion resistance.

Every Operating Executive should know these Facts about Controlling Operating Costs with Centralized Lubricant Application Systems

The outstanding contrast between the individual contact system of lubrication (oiler with oil can) and the modern centralized system is a matter of *controlling* the application of the type, quantity and time interval of the lubricant, which in turn, strongly influences machine down-time, labor and cost-saving. The centralized system refunds its cost over and over again as long as it is used, while all individual contact methods continue to increase in cost indefinitely.

Here are many of the outstanding advantages of centralized lubrication.

1. Prevents waste of lubricant.
2. Reduces man-hours devoted to lubricant application to a very minimum.
3. Reduces machine down-time for lubrication.
4. Eliminates machine down-time for repairs due to bearing failure or faulty operation of worn parts resulting from inadequate lubrication.
5. Increases productive rate and efficiency of machinery to a uniform maximum.
6. Improves quality of product.
7. Eliminates product spoilage from dripping of excessive lubricant.
8. Reduces power requirements by eliminating friction—maintains power used consistent with work done.
9. Eliminates personal injuries and corresponding compensation costs attributable to lubricant application.



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(Section News, from 94)

tories and sales of technical equipment. In conclusion, she discussed the current positions of many women engineers who have been successful and indicated that most women are being accepted by plant male personnel. (Submitted by E. Landau, Sec'y.)

NORTHERN CALIFORNIA: Feb. meeting—J. G. Howell, Jr., Owens Illinois Glass Co., presented a paper on the subject A Trip To A Typical Glass Container Manufacturing Plant, first providing a visual background by means of a color movie of the intricate machinery which is used in the manufacture of the manyfold types of glass containers. He concluded with a description in detail of the problems confronting the lubrication engineers in their effort to maintain the continuity of operation of their equipment under normal as well as adverse conditions. (Submitted by P. M. Ruedrich, Sec'y-Treasurer.)

ONTARIO: March meeting—G. Findlay, Republic Steel Corp., presented a paper entitled Steel Mill Lubrication. (Submitted by W. B. Dembner, Sec'y.)

PHILADELPHIA: Feb. meeting—Ladies Night, with G. K. Lake, Burlington Mills Corp., presenting a paper entitled Synthetics, Their Place & Use In Textiles, followed by a cartoon movie on the New York Stock Exchange.

March meeting—A panel discussion on Lubrication Equipment was presented by J. L. Beatty, L. R. & J. L. Beatty Co.; E. A. Cichcelli, Bethlehem Steel Co.; and N. Bracht, Lukens Steel Co. (Submitted by J. L. Beatty.)

SAGINAW VALLEY: Jan. meeting — Ladies Night, with A. Thom, Standard Oil Co., presenting a talk on slides taken at Korea, followed by installation of new officers (See ASLE Directory).

Feb. meeting — J. Grenier, Chevrolet Flint Manufacturing Co., presented a paper on the subject History of Lubrication For The Last Twenty-Five Years. (Submitted by N. M. Pagels.)

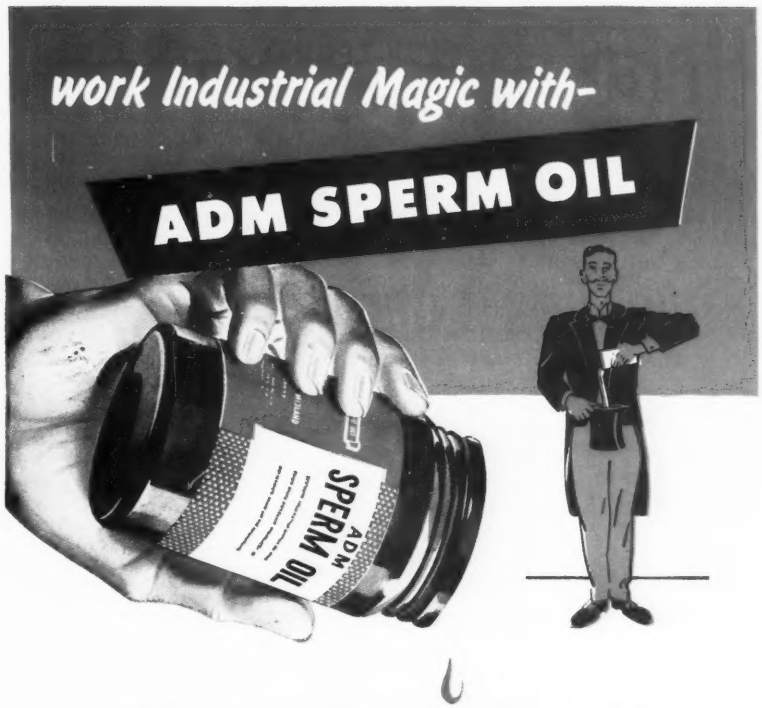
TWIN CITIES: Jan. meeting — E. Cypert, Magnolis Petroleum Co., presented a paper entitled Present & Future Of Williston

Basin Oil Production. (Submitted by W. H. Furst, Sec'y.)

YOUNGSTOWN: Jan meeting—E. J. Gesdorf, The Farval Corp., presented a paper entitled Centralized Lubrication. Excerpts include: ". . .It is a generally accepted fact that we are living in what might be termed as the "automatic age." Many of the simple tasks which were previously performed by hand are now being mechanized: in the home laundry, the introduction of automatic washing and drying machines; in the kitchen, the automatic dishwashers and the automatic disposal units; the application of automatic controls on the modern motor car. These are but a few of hundreds of similar examples that could be cited to indicate the extent to which the automatic idea has been carried.

In order to produce the various automatic devices in sufficient quantity and quality and at a price attractive to the average consumer, they are manufactured in hugh factories employing mass production methods. All mass production plants whether they be dealing with steel, rubber, paper, automobiles or home appliances, require intricate controls to assure a steady flow of raw materials into the factory—they require rigid controls to assure a steady flow of materials through the various processes, and they require controls to assure a steady flow of finished products to the points of distribution. Management has come to realize that continued operation of mechanical equipment depends upon its bearings, and that bearings in turn will operate only so long as they receive proper lubrication at regular intervals.

Due to the fact that centralized systems have offered such additional advantages as savings in lubricating time, reduction of lubricant consumption, elimination of personal hazards accompanying hand greasing, elimination of machine shutdown periods for lubrication, and assurance that all bearings are being lubricated, their use as standard equipment is being expanded daily. In a survey conducted by STEEL magazine sometime ago, of the future markets for machine tool equipment, 85.6% of all users indicated they



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Used in making sulfonated oils for tanning and dressing fine leathers in .. LEATHER TANNING

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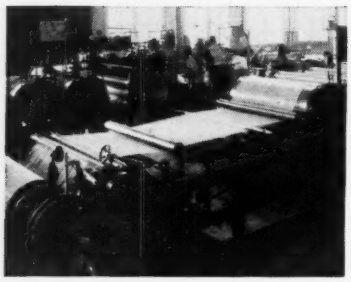
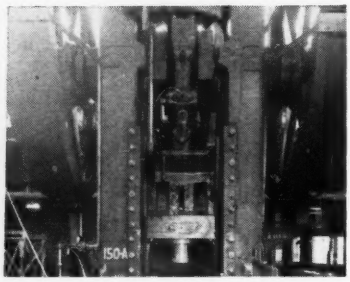
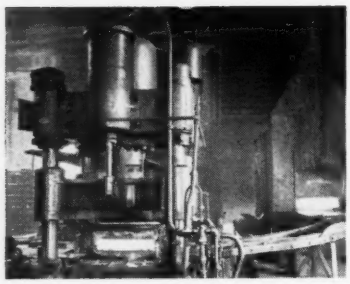
COSMOLUBE meets bearing lubrication needs throughout your plant—perfect for hot, cold and wet spots—just one grease to buy, store and apply! *No chance of misapplication!*



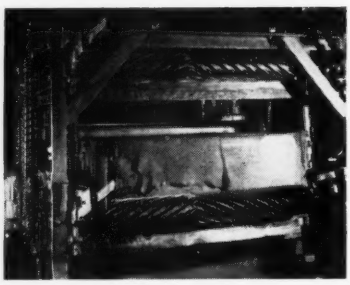
NO LEAKAGE PROBLEMS under any normal conditions because Cosmolube clings tenaciously to all metal surfaces. This adhesiveness provides better protection to moving parts.



WITHSTANDS HEAVY LOADS because Cosmolube is cold milled and stands up under extreme working stress. Its exceptional oxidation resistance also prevents deterioration in storage.



RESISTS HIGH TEMPERATURES and pumps easily at 20° below zero—ideal for varied plant applications because Cosmolube remains stable under a wide range of temperature conditions.



HIGH MOISTURE RESISTANCE is assured because Cosmolube is insoluble in hot or cold water. It provides utmost lubrication even in machinery that gets drenched with water daily.

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wanted centralized lubrication on their new tools, and in plants employing 500 people or more the vote for centralized was nearly 94%." (Submitted by R. S. Scheidemantel, Sec'y.)

(Lube in the News, from 91)

assembly and replacement service. It is currently available in sizes to fit shaft diameters of ¼, ⅜, ½, ⅝, and ¾ inches. The metallurgy of the seal, bronze, stainless steel, etc., can be specified to meet service requirements or operation conditions. For further information and engineering data write: Crane Packing Co., Dept. L-3, 1800 Cuyler Ave., Chicago 13, Ill.

MICRO-FOG LUBRICATOR: A new and unique micro-fog lubricator for bearings, spindles, gear boxes and small air powered devices has been especially designed to produce an extremely fine and uniform oil fog at low air flow. Its features include: a constant oil level to assure a uniform rate of oil feed; 360° visibility of the oil flow; accurate metering of oil delivery into the air line to as little as 1 drop in 20 minutes by means of air control; universal right to left or left to right flow without adjustment; full view of the oil supply; cools as it lubricates high speed rotating parts; prevents entry of foreign particles into bearing and spindle housing, gear boxes, etc.; greater oil fog travel; and uniform distribution of oil fog to multiple outlets. It is for ¼" air lines. Rated air requirements from 0.8 cfm. at 10 psi. to 6 cfm. at 80 psi. Maximum safe operating pressure 150 psi.; maximum safe temperature 120 F. Complete data is available from: C. A. Norgren Co., 3400 S. Elati St., Englewood, Colo.

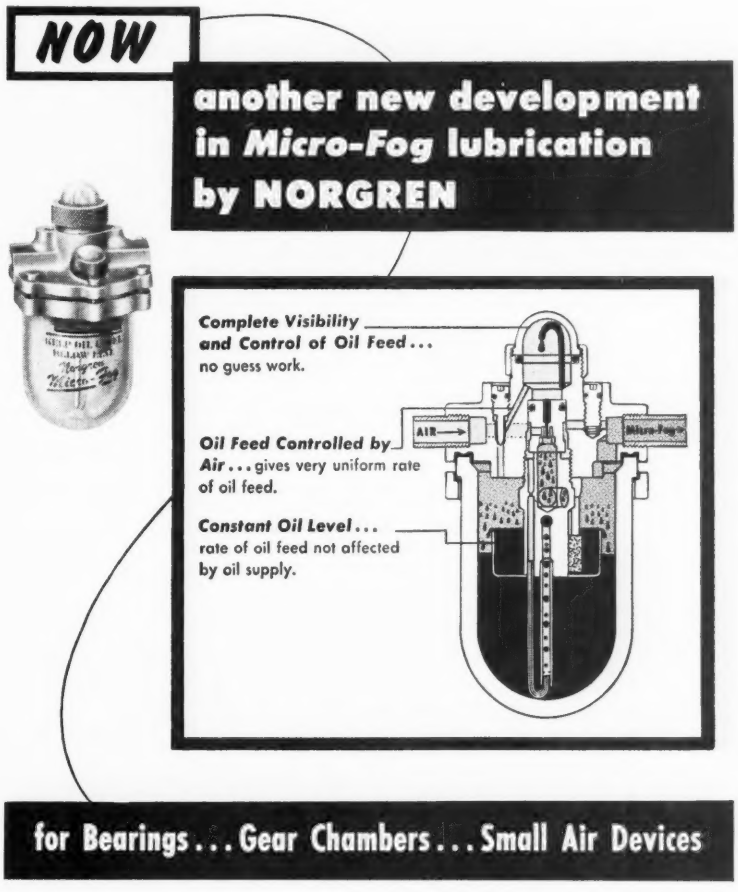
MOLUB-ALLOY is the result of a new concept in lubrication which employs petroleum as a vehicle instead of as the primary lubricating agent. Manufactured in a wide range of types and weights from high quality hydrocarbon base stock, or synthetic or volatile base materials to which has been added scientifically homogenized micron-sized particles of self-lubricating metallic solids, they act as millions

of micron-sized ball bearings. One of the metallic solids used is molybdenum disulphide. Each molecule consists of a layer of metallic alloy atoms combined with a layer of sulphur atoms. The sulphur atoms, having a strong affinity for metal, adhere to the surface and support the metallic atoms, to form a metallic lubricant which is resistant to water, high heat and high pressures and temperatures, and which has unusual tenacity or adhesiveness to metal surfaces. Manufactured as a grease in standard NLGI weights, is also available in all weights of oil for all applications ranging from heavy, exposed gears to high speed spindles. For specifications or case histories write: Imperial Oil & Grease Co., Inc., 6399 Wilshire Blvd., Los Angeles 48, Calif.

MOLYKOTE-SILICONE TYPE 77, a new lubricant particularly adaptable for use on synthetic rubber, plastics, leather, nylon and fibre bearings, and all metals, has been announced that combines all the well-known features of silicone lubricants with the extreme bearing pressure lubricity of Molykote. Chemically inert to rubber, plastics, leather, nylon, fiber and metals, it is resistant to oxidation and is not subject to gum or varnish formation. For further information write: The Alpha Corp., 179 Hamilton Ave., Greenwich, Conn.

SUNICUT 11-S, 102-S, 110-S, & 209-S, are newly developed, unique additives which keep parts and tools up to 50 degrees cooler. SUNICUT 11-S & 209-S are non-staining, dual purpose oils developed primarily for medium duty and heavy duty operations on automatic screw machines; SUNICUT 102-S & 110-S both contain active-type sulfur and are especially effective for heavy-duty screw machine work and for other heavy duty operations such as broaching, gear-hobbing, threading, and tapping. For copies of Technical Bulletins describing these products write: Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa.

TENAC, HI-TEMP OIL 303, AND COSMOLUBE 101 & 102 are three new speciality lubricants (additive treated lubricants with petroleum base) recently developed. TENAC, an open gear lubricant applied by spray, drip or brush, can be so applied because it is cut back by a solvent which, following evaporation, leaves a semi-plastic film on the gear surface. This film is tough and so adhesive that it will not be thrown off the gear by centrifugal force. HI-TEMP OIL 303, for use at temperatures of 500° and over, is light enough to be fogged easily in automatic lubricators yet provides high load carrying protection. Combining molybdenum disulphide with a synthetic base and a pure, low-carbon-content petroleum oil, it imparts exceptional lubricity, high resistance to heat breakdown and reduces carbon build-up to a minimum on bearings exposed to elevated temperatures. COSMOLUBE 101 & 102 are high temperature greases made up of non-soap base. They are a colloidal mixture and have no melting point. Both greases retain their form to the point of burning. For further information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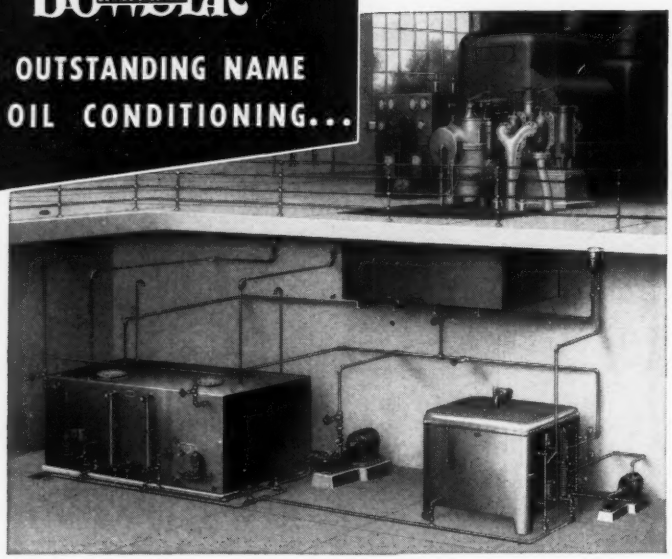

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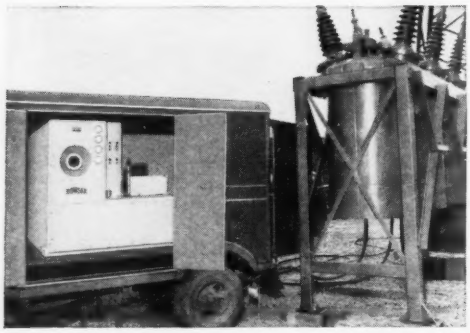
This Bowser turbine oil conditioning system keeps oil "bone dry" and crystal-clear . . . the best "stay-on-the-job" insurance a turbine bearing can have. Costly bearing failures are avoided and less stand-by equipment is required with Bowser oil conditioners. Turbine oil lasts for years, too! That's why Bowser oil conditioners are on the job in a majority of power plants.



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HOW TO SIMPLIFY & SAVE WITH PURE INDUSTRIAL LUBRICANTS, is the title of a new booklet for the harried Plant Maintenance Superintendent or Lubrication Engineer who finds himself with too few oilers and too many lubricants. This booklet sets up six simple steps to streamline lubrication programs and goes on to point out that for the average plant a maximum of six lubricants will do a satisfactory job. Copies may be obtained by writing: The Pure Oil Co., Advertising Dept., 35 E. Wacker Dr., Chicago 1, Ill.

(Current Literature, from 93)

cant stable in fuming nitric acid, dilute acid and water, and insensitive to shock and impact while in the fuming nitric acid has recently been developed, according to the U. S. Air Force. This new grease might be used to lubricate parts of rocket motors and also equipment used by ground crews in handling strong oxidizers. At present, two grades of the lubricant are proposed for use to cover the temperature range from minus 65 to 160 F. But the Air Force wants a single grease for the entire range.

LUBRICATION OF WELLS SIMPLIFIED
By Anon, World Oil, Vol. 135. No. 6, Nov. 1952, p. 225.
The 2-1/2 inch lubricator, when fully assembled, represented considerable weight, and was difficult to connect when preparing to run instruments in the well. By stretching a tightwire across all wells, a pipe ladder as shown can be secured to the wire enabling the pumper to stab the lubricator onto the well head. An additional advantage offered by the tightwire is that the lubricator may be braced against lateral movements.

NEW JET SYNTHETIC LUBRICANT DEVELOPED
by Anon, Oildom, Vol. 31, No. 11, Feb. 17, 1953, p. 156.
New synthetic silicone lubricants were developed by Murray & Johnson of the Lewis Flight Propulsion Laboratory because natural petroleum lubricants broke down at high temperatures. Solvents (diethyl hexyl or diethyl hexyl sebacate) were used to make the silicones adhere to steel and they could withstand heat.

NEW LUBE, FUEL TESTS
by Anon, Oil & Gas Journal, Vol. 51, No. 37, Jan. 19, 1953, pp. 64-65.
Three tests claimed considerable attention at the annual meeting of the Society of Automotive Engineers. The radioactive piston-ring method, the relative importance of preignition and detonation in high-compression engines, and a third new technique, a low-temperature sludging test promise further contributions to the means of evaluating lubricating oils for current and future use.

NEW SUBZERO TOOL OIL DEVELOPED
by H. C. Plummer, Petroleum Engineer, Vol. 25, No. 1, Jan. 1953, p. C—18.
Completion of a new low temperature oil as a lubricant for use in pneumatic tools, such as rock-drills and jack-hammers, where water or wet air is present, is announced by the National Research Council, Canada, and listed by the Canadian Government Specifications Board following field tests. Temperature range is between plus 40 F. and minus 50 F.

PERFORMANCE OF SYNTHETIC GREASES
by E. R. Booser, A. E. Baker & E. G. Jackson, Institute Spokesman, Vol. 16, No. 9, Dec. 1952, pp. 8-11, 13, 15-18.
As airplanes fly higher and faster, and military vehicles of all types are expected to operate equally well in the frigid Antarctic or scorching desert sands, the versatility of synthetic lubricants is being demonstrated. Silicones are used in greases for extremely low temperatures. At high temperatures the silicones also excel especially in ball bearings, although they leave something to be desired in the lubrication of gear teeth or sliding parts. The much lower cost of petroleum lubricants dictates their continued use for the majority of applications, but for the hard to solve problems encountered at extremely high or extremely low temperatures, the more costly synthetics will find increasing application.

PETROLEUM
by H. Levin, Analytical Chemistry, Vol. 25, No. 1, Jan. 1953, pp. 47-54.
As can be seen in the four previous annual reviews and generally in the field of analytical chemistry, the adaptation of instrumental methods to the solution of various problems continue to be the major trend in the analytical phase of petroleum technology. This is apparent again in the following review, which covers the literature for a period of one year from that covered in the previous review. 182 references are given.

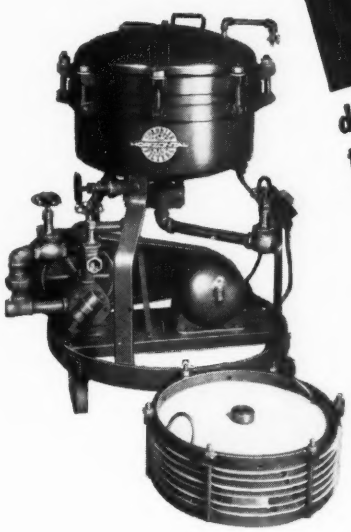
PHOSPHORUS IN THE LUBRICANTS FIELD
by C. V. Smalheer & T. W. Mastin, Petroleum Processing, Vol. 7, No. 12, Dec. 1952, pp. 1780-1784.
This article was presented at a recent meeting of the American Chemical Society. It is concerned primarily with lubricant developments relating to the reciprocating internal combustion engine and its use to provide motive power, through appropriate transmission devices, for vehicles of all types. The role of phosphorus and its compounds in this area of the lubricant field is an important one. The chemistry of phosphorous bearing additives is discussed and emphasis is placed upon recently more widely accepted types. 28 references are given.

PREPARATION & PROPERTIES OF SILICA AEROGEL-THICKENED GREASES
by E. C. Milberger & L. J. Swatik, Institute Spokesman, Vol. 6, No. 10, Jan. 1953, pp. 18-21, 23-24, 26-29.
Silica aerogel-thickened greases are thickened lubricants wherein a finely divided silica is used as the gelling

Keep your hydraulic oils, and coolants clean with . . .

SPARKLER FILTERS

designed specifically for this purpose. A practical protection for hydraulic machinery and cutting tools



The VR filter is designed for filtering hydraulic oil, quenching oils, transformer oil, solvents and other industrial liquids.

The Sumptype filter is ideal for filtering coolants. The filter plate assembly is attached to the intake pipe of the circulating pump and the coolant is drawn through the filter discs and delivered clean and free from all metal particles and grit, to the nozzels.

★ Clean hydraulic oil greatly prolongs the life of all moving parts, such as pistons, cylinders, pumps, valves, etc.

★ Filtering hydraulic oil extends the life of the oil. Drain and leakage oil may be reclaimed. One large user of hydraulic machinery saved $90,000.00 in hydraulic oil alone in one year by filtering oil with Sparkler Filters.

★ Filtering hydraulic oil eliminates sticking and clogging of valves and reduces down time and maintenance cost. A prominent authority on hydraulic machinery says that 70% of servicing and repairs is due to the improper condition of hydraulic oil.

★ Filtering coolant fluid removes all fine metal particles and grit from grinding wheels that is pumped back to nozzles unless a filter is employed in cleaning up the return coolant.

★ Clean filtered coolant prevents scratching and flat spots on work piece and increases the life of grinding wheels and cutting tools. Reduces the frequency of dressing grinding wheels.

The Sparkler VR filter is constructed on a simple filtering principle using filter paper as a media. The filter plates can be removed easily for cleaning which consists only of removing the dirty paper and replacing with fresh sheets. Any shopman can make this change of paper in a few minutes. The cost of replaced paper is less than a dollar per change.

Let a Sparkler representative demonstrate these filters in your plant

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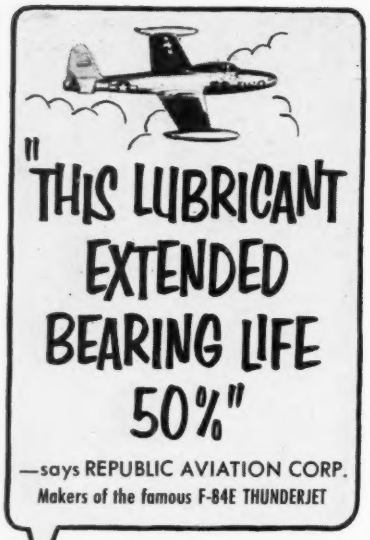

"Under actual tests, LUBRIPLATE extended bearing life fifty per cent or better as compared to other lubricants. It was also found that, during test, LUBRIPLATE increased efficiency of machines twenty per cent by reducing friction loss. Republic has been using LUBRIPLATE successfully for the past eight years."

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agent instead of soap. The silica content is non-abrasive as shown by laboratory tests and by field performance. These greases are characterized by extreme ease and reproducibility of preparation at ordinary temperatures and with conventional mixing equipment. When properly compounded with suitable additives, they are shown to possess water resistance, consistency stability at high temperature and to working, excellent oxidation resistance, and low bleeding tendencies.

PROTECTION OF ENGINES DURING SHIPPING & STORAGE
by R. K. Ross, Scientific Lubrication, Vol. 4, No. 12, pp. 10-15.
The author traces the techniques of internal engine corrosion preventives from the pre-war years to the "drive-away" oils of today and makes special reference to the problems experienced in Australia during the war years in protecting the equipment of Allied troops engaged in jungle warfare. U. S., British, Canadian, and Australian specifications for corrosion preventives are discussed.

SOUND CLEANING
by Anon, Esso Oilways, Vol. 18, No. 18, Dec. 1952, p. 20.
According to George E. Henry of the General Electric Co., ultrasonic waves when passed through petroleum solvent contained in a machine oil sump, for instance, will cause the solvent to do a better cleaning job than is possible by the use of solvent alone. The cleaning action of the solvent in removing sludge, lapping compound, metal particles and other unwanted deposits is very fast and effective when used in connection with ultrasonic waves. Small machine and product parts immersed in solvent are quickly freed of particles clinging to their surfaces, when ultrasonic waves are passed through the solvent.

SPECTROGRAPHIC DETERMINATION OF TRACE ELEMENTS IN LUBRICATING OILS
by R. F. Meeker & R. C. Pomatti, Analytical Chemistry, Vol. 25, No. 1, Jan. 1953, pp. 151-154.
The use of the emission spectrograph, by operators and builders of heavy Diesel-powered equipment and oil companies, to study engine wear and corrosion by analysis of the used oil is becoming increasingly popular. This applies particularly to railroads in connection with maintenance of Diesel locomotives. Because the determination of several elements, usually occurring in the order of a few parts per million or less, is required in studies of this type, the spectrograph provides a convenient, relatively rapid, and often the only economically practical means of analysis. Analysis of an individual sample of used lubricating oil will, by itself, yield information of little value. Such analyses must be correlated with the service records of the equipment and oils involved, and actual engine wear data. Results are tabulated.

(Patent Abstracts, from 95)
an oil-in-water emulsion, Water, a high boiling organic liquid coupling agent, and about 0.2-2.0% by weight based on the soluble oil of an aromatic alkylene diamine selected from the group consisting of benzyl alkylene diamines and salicylal alkylene diamines effective to inhibit said soluble oil against steel corrosion in the presence of water.

BENTONITE GREASES, Patent #2,626,241
by W. J. Sparks, A. J. Morway & D. W. Young, assignors to Standard Oil Development Co.
A lubricating composition consisting essentially of a synthetic lubricating oil thickened to a grease consistency with a complex formed by reacting bentonite with an aliphatic amine salt, said synthetic lubricating oil being the residue remaining after distillation at about 250 C. of the mixture of products obtained by subjecting a C_7 monoolefin to the action of carbon monoxide and hydrogen in the "Oxo" process.

TORQUE CONVERTER FLUID, Patent #2,626,242
by S. K. Talley & F. J. Watson, assignors to Shell Development Co.
A power transmission assembly comprising a friction drive transmission and as a lubricant therefor a mixture of tertiary alkylated naphthalenes having an average alkyl substitution from 1:1 to 4:1, an average viscosity index of −50 to −400, at least 90% of said alkylated naphthalenes boiling within the range 200 C. to 500 C. at 760 mm. mercury pressure.

PROCESS FOR PREPARING ALKALI METAL GREASES, Patent #2,626,896
by J. P. Dilworth, G. W. Eckert & W. J. Coppoc, assignors to The Texas Co.
Lubricating greases comprising mainly a dehydrated mixture of 15 to 25% alkali metal soaps of a soap-forming material having an iodine number of at at least 40, 60 to 80% mineral oil and 1 to 3% alkali metal hydroxide, said mixture having been subjected to digestion at a temperature of 300 to 390 F. and at an air pressure of 50 to 120 pounds per square inch for at least 5 hours.

ALUMINUM SOAPS, Patent #2,626,897
by W. A. Young & J. C. Zaborski, assignors to Sun Chemical Corp.
A lubricating grease comprising mineral oil and from approximately 2% to approximately 20% by weight of the grease of an aluminum soap of a plurality of soap-forming acids, said acids consisting for approximately 98%-75% by weight of a saturated higher fatty acid of at least 16 carbon atoms and for approximately 2%-25% by weight of dimerized linoleic acid and an acid of the group consisting of saturated organic carboxylic acids of from 4 to 10 carbon atoms, each of the latter two acids constituting not less than 1% and not more than 15% by weight of the total amount of the said soap-forming acids.

PROCESS FOR PREPARING ALKALI METAL GREASES, Patent #2,626,898
by J. P. Dilworth, G. W. Eckert & W. J. Coppoc, assignors to The Texas Co.
A process for preparing alkali metal greases which comprises saponifying a mixture of a mineral lubricating oil fraction, an aqueous solution of alkali metal hydroxide and a soap-forming material selected from the group con-

sisting of soap-forming acids, soap-forming esters and mixtures thereof, said alkali metal hydroxide being in excess of the stoichiometric amount required for saponification of said soap-forming material, dehydrating said mixture and digesting said saponified and dehydrated reaction mass at an elevated temperature of 300 to 390 F., at an air pressure of 50 to 120 pounds per square inch for a period of at least five hours, cooling and drawing said reaction mixture.

MINERAL OIL COMPOSITION, Patent #2,628,939
by E. S. Blake, assignor to Monsanto Chemical Co.
A composition of matter useful as a lubricant consisting essentially of a major amount of mineral oil the lubricating properties of which are enhanced in the respect that the wearing of lubricated metal surfaces is reduced by having incorporated therein in amount effective to reduce wear an additive composition containing 5.8%-11.4% sulfur and 0.11%-0.80% phosphorus supplied essentially by a sulfurized and phosphorized ester of the group consisting of ethylene glycol dioleate, diethylene glycol dioleate and dithio diglycol dioleate obtained by heating with sulfur at 150-200 C. and phosphorizing at 100-125 C.

EXTREME PRESSURE LUBRICANT, Patent #2,628,940
by E. B. Cyphers & W. E. Waddey, assignors to Standard Oil Development Co.
A lubricating oil additive material having the characteristic of imparting desirable extreme pressure properties to a lubricating oil with which it is blended consisting of about 50% by weight of a reaction product of a chlorinated wax-kerosene mixture with sodium polysulfide, about 30% by weight of a P_4S_3-treated sulfurized methylated rosin, and about 20% by weight of a P_4S_3-treated sulfurized sperm oil.

EXTREME PRESSURE LUBRICANT, Patent #2,628,941
by D. E. Adelson, G. L. Perry & G. G. Pritzker, assignors to Shell Development Co.
A lubricating composition comprising a major amount of a liquid organic lubricating base having incorporated therein from about 0.01 to 10% of a reaction product obtained by reacting an aliphatic compound selected from the group consisting of C_2—C_5 alkylene oxide, C_2—C_5 alkylene sulfide, and C_2—C_5 alkylene imine with an organic poly acidic compound containing from 1 to 3 free carboxylic acid groups and at least one hydroxy group, said reaction being carried out at a temperature of at least 75 C. in the mole ratio of from 4:1 to 12:1 respectively.

LUBRICATING OILS CONTAINING METAL DERIVATIVES OF CYCLIC IMIDES, Patent #2,628,942
by J. R. Morris & J. R. Roach, assignors to The Texas Co.
A lubricant consisting essentially of a refined mineral lubricating oil and a small amount sufficient to improve the detergency thereof of a compound.

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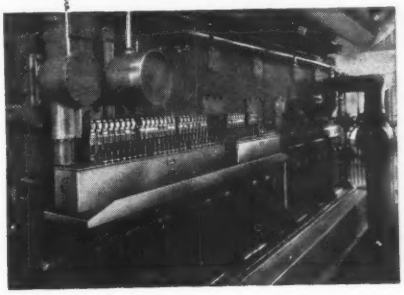

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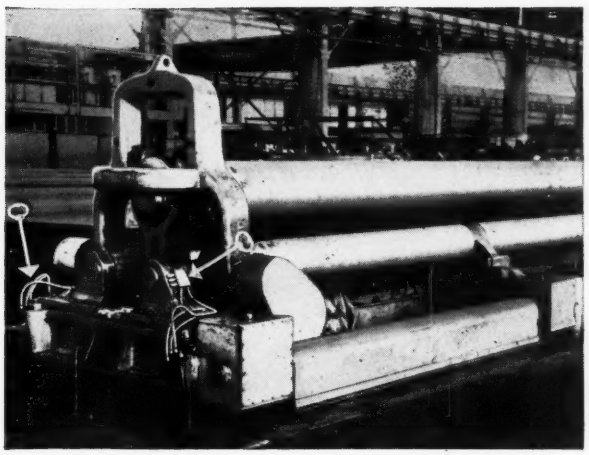
FARVAL—

lubricated by Farval



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FARVAL SAVES ON BENDING ROLL LUBRICATION

	Lbs./yr. lube. 62 points	Hrs./yr. lube. 62 points	Annual Cost @ $1.50/hr. 62 points
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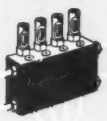
CENTRALIZED SYSTEM	5,304 lbs.	15 hrs.	$ 22.50
COMBINED SAVING (LABOR AND LUBRICANT)			

Reports of lubrication engineers show lubrication by grease gun takes .747 minutes per point—to clean dirt from nipples, grease, move from point to point, and refill gun. With Farval it takes only 15 minutes every fourth day to refill Farval reservoir. In addition, Farval saves 3 pounds of each 4 of lubricant used by other methods.

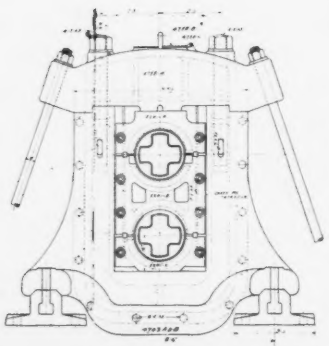
FARVAL

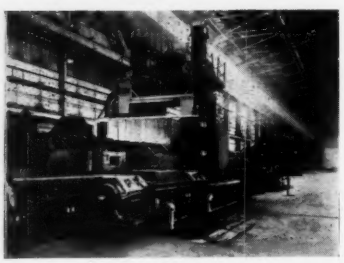


CENTRALIZED SYSTEMS OF LUBRICATION

HODSON'S

GEARKOTE





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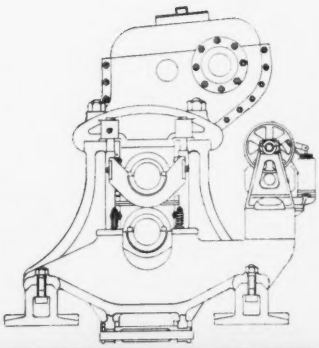
Blooming mill entrance, delivery table and drives.
GEARKOTE installed 1939

Blooming mill pinion.
GEARKOTE installed 1926

Universal mill.
GEARKOTE installed 1928

Five high mill pinion.
GEARKOTE installed 1927

Traction gears of Diesel locomotives.
GEARKOTE installed 1926

Alloy mill pinions, necks and teeth.
GEARKOTE installed 1937